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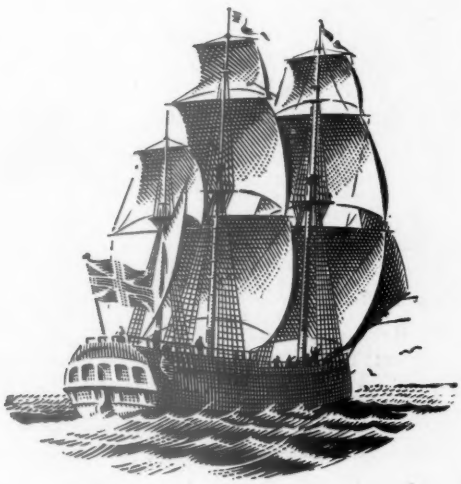
ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind



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Endeavour

VOLUME I 1942

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JANUARY 1942

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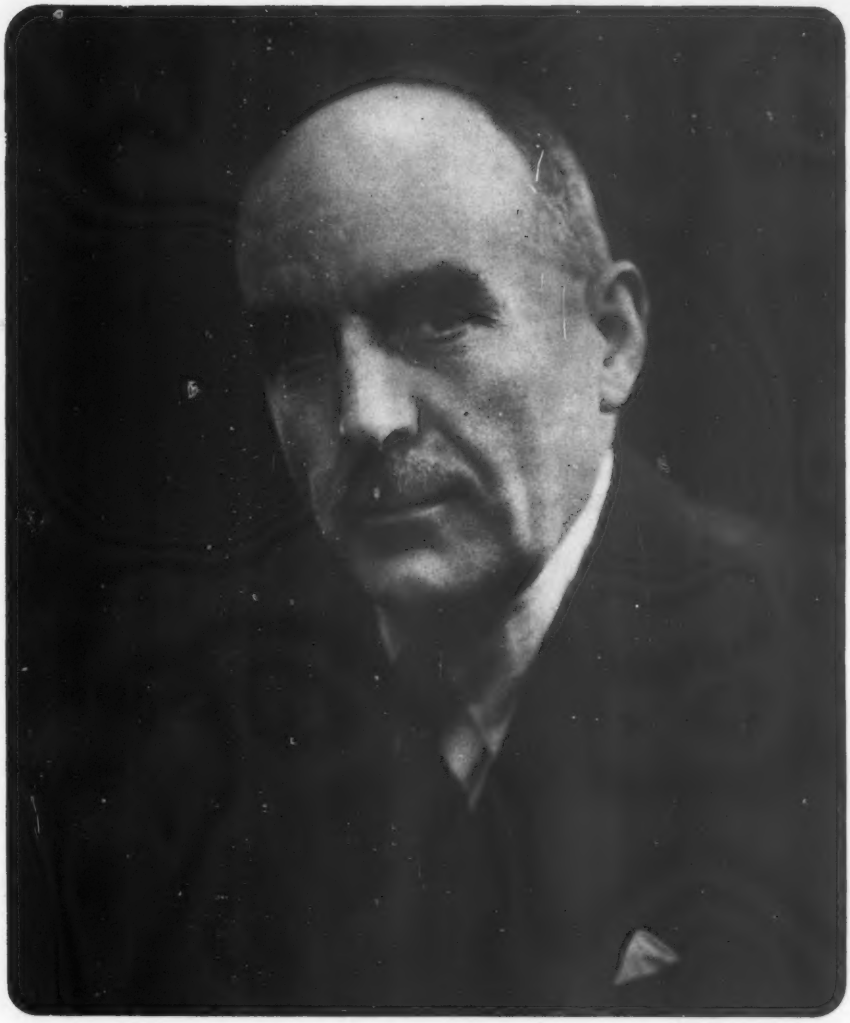


THE ASTRONOMER ROYAL

Dr Spencer Jones, author of the main article in this issue, has been Astronomer Royal since 1933. This is the premier as well as the best known astronomical appointment in Great Britain, and perhaps in the whole world, on account of its seniority and the number of distinguished men who have held it.

The first holder was John Flamsteed, appointed Astronomical Observator in 1675, whose name is immortalized in a series of observations from which modern astronomy may be said to have begun. His successor Edmund Halley (1720-42) was equally famous both for the discovery of the comet which bears his name and for his investigations of the tide. Other eminent holders of the appointment were James Bradley, Nevil Maskelyne, John Pond and Sir George Airy.

The Astronomer Royal works in the Royal Observatory at Greenwich, which is the foremost international station for the measurement of time.

Our purpose

It is the duty of a new periodical on its first appearance to make declaration of the purpose for which it has been born. We are happy to do this by reference to a letter from PROFESSOR A. V. HILL, Secretary of the Royal Society, which is to be found in our Correspondence columns. Professor Hill recalls that in the year 1768 the great British navigator, Captain James Cook, set sail from England in the barque *Endeavour* to chart the South Pacific Ocean and observe the transit of Venus. He was accompanied by several men of science, including Sir Joseph Banks, a celebrated botanist of the period.

There are two or three things about this enterprise which are worthy of notice today. There is the continuity of the close association of the Royal Society with British scientific developments throughout the two hundred and eighty years of its existence. Sir Joseph Banks was President of the Society from 1778 to 1820, and Captain Cook was elected a Fellow in 1776 in recognition of his services to science. We are proud to be able to publish messages from today's President, SIR HENRY DALE, as well as from the Secretary. Then there is the evidence of the democratic spirit which animates the history of the British peoples, and has resulted in the emergence of many of our greatest men from humble surroundings. Cook was the son of an agricultural labourer and began his career as an apprentice in a coasting collier. Yet these undistinguished antecedents did not prevent him from entering the Royal Navy nor, once he was in it, from advancing so rapidly that he was no more than 40 years of age when he was appointed to command an expedition organized specifically for scientific purposes. And that is the third and, so far as we are here concerned, the most significant fact: that nearly two centuries ago the British Admiralty should see fit to equip a vessel and finance a cruise for the express purpose of carrying out exploration and research in the interests of science. It was only a small vessel, a sketch of which appears on our cover, but the fact remains that it carried overseas British men of science bent on making investigations for the advancement of learning.

We accept a like responsibility, and hope to be able to justify Professor Hill's confidence that our ENDEAVOUR will act as a vessel to carry overseas news of the continuing vitality and progress of the sciences, which know no frontiers but are directed to improving the common lot of all men. Our purpose is briefly to enable men of science, and particularly British men of science, to speak to the world in an hour when not only nations but the internationalism of the sciences are threatened by a recrudescence of barbarism in its grossest and most destructive manifestation.

Science is not the product of any one race, or of any one age. The Egyptians were the first agriculturists, the Babylonians the first astronomers, the Greeks mathematicians and physicians, the Arabs chemists: every country of Europe has played its part in pushing forward the frontiers of scientific knowledge; and the New World has proved itself the peer of the Old. Britain, however, may contemplate with particular pride the disproportionately long list of her sons who have made outstanding contributions to natural knowledge—a fact to which we are able to direct attention elsewhere in our columns—beginning with Roger Bacon in the thirteenth century and continuing with his even more famous namesake Francis, Newton, Boyle, Hooke, Mayow, Dalton of atomic theory fame, Davy, Faraday, Darwin, Thomson, and countless others. There is no country with a record more brilliant, and the torch is still carried high.

It is the aim of ENDEAVOUR to see that in these dark days its light is thrown overseas, especially to those parts of the globe where intimate contact with Great Britain is at present more difficult to maintain. We do not apologise if these pages lay emphasis on British scientific work. That is our particular pride. But that they will not be marked by any narrow insularity is, we are confident, sufficiently guaranteed by the contents of this inaugural number.

Science and the community

SIR WILLIAM BRAGG

The present position of science and the applications of science are causing many of us to think furiously. The conclusions that are reached are varied; often they are mutually contradictory. It is clear that thinkers are starting from differing premises, which must be imperfect in some cases, and are influenced by different outlooks on life.

What Hitler thinks is plain enough. He and his people have grasped the fact of the tremendous powers of science in war. The German scientist has been put to the study of every form of natural knowledge which can enable the Nazi forces to wound, crush, and kill their opponents. Science has been applied to the design of ever more powerful guns, not to the increase in the supply of butter for the health and well-being of the people. Health is indeed considered, and nutrition is studied to an extent which can be an example to other nations, but the man is to be healthy and strong so that he may be a good soldier of a Reich trampling on the rest of the world. The great and ever-growing powers of science are understood, but the ideals are desperately wrong. Our side of the war shows an equal appreciation of science, later in time than that of the enemy, but not less thorough. Indeed, we begin to think that in some respects we are leading. The Allies are fighting for a better world than Hitler has in mind. To achieve it we must beat him with his own weapon.

What about the ordinary man, ordinary in the sense that he has not spent many years at school and is now earning his living as artisan or clerk or shopkeeper, or, it may be, is enlisted for the duration of the war? He is by no means inappreciative of what science can do: the wireless set and the aeroplane are continually before him as efficient witnesses. He does not know much about the patient development of the laboratory which has made such things possible. He is quite capable of understanding the part that science now plays in the nation's affairs, in his own business and his trade, in his home and his food, in the well-being and happiness of himself and his children; and he can be made to see that those whom he elects to be his governors must understand it also.

There were once theologians who looked on all science as a deadly enemy. But the clamour of that unfortunate battle has largely died down. The religious leader and the scientist continually find themselves fighting side by side for the alleviation of want and distress and for the prevention of disease. There at least their common purpose brings them together and the discord is resolved.

What are the thoughts of the man of the public school brought up on an old tradition which was indifferent to natural knowledge? He believes, and rightly so, that he guards an ancient and imperative knowledge of men which must not be dethroned. But the old system has been too engrossed in itself. From sheer refusal to see and consider the vast changes that have been coming over the world, it has difficulty in accommodating itself to them. There is change nevertheless, and that is very welcome, for we must have the spirit which the old education was meant to inspire. Science is not incapable of becoming a new source of that spirit; but how much more helpful and effective it will be if we all march together!

There is the industrialist, the employer of labour. In these recent years he has in general become aware of the powers of science in his business. Scientific research is a part of the machinery of nearly every industry; its adoption as such was doubtless due in considerable measure to the lessons of 1914-18. It is to the honour of many leaders of the business world in this country that they have seen how the selfish use of science can end in a cruel tyranny, and have laboured to devote it to the well-being both of those whom they serve and of those whom they employ.

What does the politician think about science? His thoughts are clearly very varied and his ideas of its use are often ill defined. That must be so since our rulers are drawn from different groups of men, including those already mentioned. The one group that is sparsely represented in Parliament is that of the scientists themselves. The present House contains only one who can be described as a working scientist. Consequently there are some who are

suspicious of science, being ill acquainted with it, and others who have a vision of what may be accomplished by its means. Perhaps the majority suspends judgment. Departments of State are unavoidably dependent on science in these days: some welcome it and make good use of it. Others reluctantly admit it into their service.

Lastly, what does the scientist think himself, and what is his purpose? Of course, he must generally make his living by his work, and his thoughts may go no further for most of the time. But all scientists have at least an occasional vision of a vast and right use of their science for the benefit of mankind, and sometimes they can so display their vision that they carry the world with them.

Can we bring these very different thoughts into harmony by amending and enlarging the knowledge on which they are based? Can we bring it about that the politician and the man in the street, the theologian and the man of letters, the industrialist and the soldier, and the scientist himself, are so well informed that their thoughts are interchangeable? Can we induce each type of man to speak with sympathy for the various conditions and minds of those whom he addresses?

We must show that it is possible to observe the past growth of scientific ideas from the time of their inception through their development by thought and experiment and practice until they influence the minds of men and affect their lives. We must show how the present growth is to be watched so that the right advantage may be taken of it; we have to ward off the plunderers from the harvest and see that it is reaped for the well-being of men.

This magazine, of which the present number is the first to be issued, is an endeavour to add to the common understanding of science and of its influence upon the community. The founders are moved by conviction that this understanding is now of vital importance, and their earnest wish to contribute thereto is represented in the title under which their effort appears.

Correspondence

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., c/o Imperial Chemical Industries Limited, Nobel House, Buckingham Gate, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

MESSAGES OF WELCOME

From Sir Henry Dale, C.B.E., M.D., D.Sc., LL.D., F.R.C.P., *President of the Royal Society*

I am glad to have the opportunity of wishing all success to the new scientific quarterly ENDEAVOUR. Now, of all times, it is important that we should be reminded that science has still its proper uses, for the saving and the enrichment of human life, and for the enlargement of man's knowledge and understanding of his material environment. It is a matter for congratulation that British enterprise can now be made available to keep these permanent values before the eyes of the world.

From A. V. Hill, M.A., Sc.D., O.B.E., F.R.S., M.P., *Secretary of the Royal Society*

In 1768 CAPTAIN JAMES COOK (F.R.S. 1776), accompanied by SIR JOSEPH BANKS (F.R.S. 1766, President 1778-1820) and other scientific men, set sail in the *Endeavour* to observe the transit of Venus and explore the South Pacific Ocean. May your ENDEAVOUR record discoveries as famous as those made by Captain Cook!

From Sir Robert Robinson, M.A., D.Sc., Hon. LL.D., F.I.C., F.R.S.

It is perhaps not generally known that Imperial Chemical Industries, in addition to sponsoring

and financing specific investigations, have made considerable annual grants to heads of university laboratories with the object of promoting research activities generally.

The foundation of ENDEAVOUR shows a further generous recognition by the corporation of the importance of encouraging scientific workers and of making the results of their labours known far and wide. British chemists welcome this enterprise and wish it every success. It will foster international intellectual co-operation, and there is a definite need for a journal of reviews of recent progress designed not so much for the specialist as for the general scientific reader.

From Sir Richard Gregory, Bt., F.R.S.

The publication of a quarterly scientific review having the scope and intention of ENDEAVOUR will be warmly welcomed by students of science everywhere, whether engaged in teaching or research, or as laymen watching with intelligent concern the growth of natural knowledge and its influence upon intellectual and industrial expansion. The review will be a survey of progressive scientific thought and work, with particular reference to British achievements and their contacts with scientific discovery and development throughout the world. I like to think of it as providing what has long been wanted—a medium which reflects with clearness and authority both academic learning and technological advances related to it. The magazine can thus represent a federation of British science and industry and undertake the functions of a university extension organ in the broadest sense.

Twenty years ago, the late MR E. W. SCRIPPS —a well-known newspaper proprietor and editor—placed the sum of £100,000 at the disposal of a board of trustees in the United States to promote the education of the community in the scientific factors which vitally influence human welfare and progressive development. The news agency entitled *Science Service* was founded with these objects and has become a very effective means of interpreting scientific discoveries and inventions of every kind to the general public. It is in the same spirit that Imperial Chemical Industries decided to establish a scientific quarterly which will provide authoritative articles of permanent value for readers whose minds require something more than transient news or sensational announcements. As the review is to be published in Spanish, French, and German, as well as in English, its appeal and its influence will be much more than national, and the response to them will be world-wide from all who cherish the pursuit of knowledge, either for its own sake or for its applications.

From Sir John Russell, D.Sc., F.R.S.

Scientific activity is now so widespread and so far reaching in its effects on human life that public knowledge of its results, and some directive organization of its efforts, have become indispensable. Any kind of organization that tended to hamper the freedom of the scientific worker in thought, expression, or investigation would, however, be fatal. The best type of direction in science is that which grows out of full, free, and frank discussion illuminated by well-designed experiments; the dominating purposes must be the search for truth and the promotion of human welfare. In so far as the journal can achieve these aims it will deserve and will secure all good wishes for success.

From Sir Joseph Barcroft, C.B.E., F.R.S.

I wish the journal every possible success, and I do not doubt that it will have a useful and brilliant future. I hope the years ahead of us after the war may bring about a large expansion of British applied science—more especially in the very high-grade lines in which some other nations have been ahead of us in practice, if not in theory.

From Sir James Jeans, O.M., F.R.S.

Everything is to be welcomed which will make our own nation more acquainted with the methods and results of science, will inculcate a scientific method of approach to practical and social problems, and above all will help to make the beneficent advances of science the common property of all nations and of all races. For these reasons I welcome the appearance of ENDEAVOUR, and wish it outstanding success.

NATIONAL PARKS

From Julian S. Huxley, M.A., F.R.S., *Secretary of the Zoological Society of London*

In the spate of projects for reconstruction, I hope very much that the question of the conservation of wild life will not be overlooked. Considerable steps have been taken towards this, notably the establishment of National Parks, such as the Kruger National Park in South Africa, the Parc National Albert in the Belgian Congo, and various National Parks in Canada and the U.S.A.; and also the important London Convention Relative to the Preservation of Fauna and Flora (Africa), which came into force in 1936.

However, Great Britain, though it has taken the lead in securing the African Convention and in preparing to set up similar conventions for Asia and other parts of the world, is very behindhand in the matter of National Parks, both in Britain itself and in the Colonial Empire.

From the point of view of biological interest, the establishment of National Parks in the Colonies is obviously the more important. We have, in various parts of the Colonial Empire, and notably in East Africa, an unrivalled assemblage of interesting wild species which, however, is slowly but surely dwindling before the inroads of commercial and social development. These wild species constitute an irreplaceable heritage for the whole world, of the greatest scientific value; in addition, as anyone who has seen herds of big game in Africa can testify, they constitute a spectacle of unrivalled interest which, if properly conserved, can become the basis of a valuable tourist industry. The question of delimiting and establishing National Parks in the tropics is intimately bound up with science, since it is essential that proper surveys should be made of areas suitable for National Parks, to make sure that they do not contain reserves of valuable minerals, etc., which ought to be exploited in the interests of the world.

Another scientific aspect of the question, which is often neglected, is that of the scientific management of nature reserves and National Parks. Once man steps in, the balance of nature is distorted, and without careful management, undesirable or relatively uninteresting species may multiply at the expense of desirable or more interesting ones. This is especially true in small nature reserves in civilized countries, but applies also to a considerable degree even in large tropical areas. The problem is an ecological one which involves careful study both by botanists and zoologists, while the sociological aspects of the matter should also not be neglected.

CO-OPERATION BETWEEN UNIVERSITIES AND INDUSTRIAL TECHNICAL STAFF

From E. N. da C. Andrade, D.Sc., Ph.D., F.Inst.P., F.R.S., *Quain Professor of Physics in the University of London*

I think that it will be generally agreed that a closer connection between the industrial laboratories and the scientific departments of the universities is a thing greatly to be desired after the war. In the course of my present work I have had to visit the laboratories of various large concerns which I did not normally enter and have been struck by the wide scientific interest of much of the work in hand—an interest wider than those engaged in it always realize—and by the friendly eagerness with which suggestions have been received. My experience is, I believe, a usual one. I take it, then, that the necessary state of mind exists on both sides for cordial co-operation, but I have not so far seen any specific plans for putting into effect the desired collaboration.

After the last war a plan was tried of having work carried out in university laboratories, under the general supervision of university professors, by scientists in the employ of industrial firms. This, if successful in some cases, certainly was not in all. It has occurred to me that a modification of this plan might be tried, namely to have certain researches which are being carried out in the laboratories of industrial concerns and research associations put under the general guidance of university professors or other teachers.

I am not thinking, of course, of the main lines of research of the laboratory in question, which are being pursued by teams of specialized workers under experts of proved achievement and long experience, but rather of inquiries, initiated on points a little removed from these main lines, which are occasionally entrusted to comparatively junior workers, whose general

scientific experience and knowledge of the particular subjects are sometimes a little limited. Be that as it may, what I contemplate is that the laboratory shall invite an academic expert who enjoys their confidence to co-operate in the planning of the particular piece of work, and subsequently to visit the laboratory at convenient intervals, to guide, or take part in guiding, the progress of the investigation. From such visits one might hope to see grow up spontaneously, under natural conditions, a wider co-operation. Common interest in a definite inquiry, however small, would lead, if the original choice had been wisely made, to more extended sympathies. Our commercial laboratories possess an immense store of specialized knowledge and leaders of great insight, but occasionally a fresh point of view, such as may occur to one not in daily contact with the subject, is stimulating.

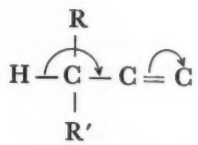
Even if the suggestions made in this letter fail to win support, I trust that it may nevertheless serve a purpose by directing the attention of more fertile and experienced minds to finding an easy and practicable way of bringing about the desired co-operation.

Work in progress

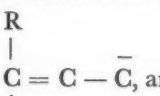
POLAR EFFECTS OF ALKYL GROUPS

Contributed by J. W. Baker, M.A., Ph.D.

To explain why the order Buγ > Prβ > Et > Me for the electron-release of alkyl groups by the inductive mechanism is sometimes upset and even completely inverted, J. W. BAKER and NATHAN (*J. Chem. Soc.*, 1935, 1844) postulated a superposed electron-release by a tautomeric mechanism arising from conjugation of the electrons of the C–H bond with an attached unsaturated system—



This should include a mesomeric (polarization) effect, operative in the ground states of such molecules and arising from resonance involving

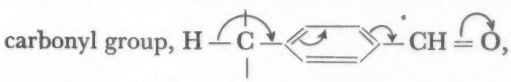


structures of the type, and an electromeric (polarizability) effect operative only in the transition complexes of reactions which require such electron-release (Baker, *ibid.*, 1939, 1150). Such tautomeric effects would give rise to electron-release decreasing in the order CH_3 (R′ = R = H, three such bonds) > CH_3CH_2 (R = CH_3, R′ = H, two such bonds) > $(CH_3)_2CH$ (R = R′ = CH_3, one such bond) > $(CH_3)_3C$ (no such bond).

An *electromeric* effect decreasing in this order has been verified by Hughes, Ingold and Taher (*ibid.*, 1940, 949) in the unimolecular solvolysis of *p*-alkylbenzhydryl halides. To establish the reality of the *mesomeric* effect BAKER and (MISS) HEMMING are making a study of the equilibrium

$$p\text{-}RC_6H_4.CH{:}O + HCN \underset{k_2}{\overset{k_1}{\rightleftharpoons}} p\text{-}RC_6H_4.CH(OH)\text{-}CN$$

(R = alkyl), in which only the relative energy levels of the ground states of the aldehyde and its cyanohydrin are involved. It is anticipated that the mesomeric electron-release would be more important in the aldehyde since here conjugation the C–H bonds extends to the side-chain carbonyl group,



whereas in the cyanohydrin it is limited to the benzene ring. The *p*-alkyl substituent should thus stabilize the aldehyde relative to its cyanohydrin in the order Me > Et > Prβ > Buγ and such differential stabilization should be revealed in the values of $\Delta F = -RT\log K$. Experimental methods have been worked out whereby the values of the equilibrium constant K and of the velocity coefficients k_1 and k_2 can be determined at different temperatures, and the results so far obtained confirm the expected order of mesomeric electron-release.

The distance of the Sun

H. SPENCER JONES

The Astronomer Royal has recently completed the most accurate determination yet made of the Sun's distance from the Earth, from data based upon co-operative work at twenty-four observatories scattered over the five continents. The Sun's distance is the fundamental distance in astronomy and enters into any calculation of distances and masses, of sizes and densities, of planets or their satellites, or of stars. The scale of the whole universe is built up on this distance. The new result is an outstanding British contribution to science.

The problem of the determination of the distance of the Sun is one of the most important in astronomy. This distance provides our standard yard-measure, on which the measurement of all distances in the universe is based. It is the fundamental datum in astronomy and enters into almost any calculation of distances and masses, of sizes and densities either of planets or of their satellites, or of the stars. Any error in its determination is multiplied and repeated in many different ways, both in the solar system and in the universe as a whole. In all ages the Sun's distance has been the object of inquiry, and it still attracts the attention of astronomers because the problem of its determination to an accuracy of one part in a thousand presents great inherent difficulties. An error in measurement that would set the Moon nearer to or farther from us than she really is by 100 miles would produce an error of 16,000,000 miles in the distance of the Sun. A new determination of this distance, based on investigations that have extended over twelve years, has just been completed and has provided by far the most accurate measure of the Sun's distance ever made. The distance proves to be 93,005,000 miles with an uncertainty of only 9,000 miles.

If the distance of the Sun is to be determined by direct observation, it must be by the measurement of an angle. This is exactly what the surveyor does in the measurement of the Earth's surface by the process called triangulation. He starts with an accurately measured base-line and determines the distance of a distant point by measuring, from each end of the base-line in turn, the angle between the base-line and the direction to the distant point. This enables him to calculate the distance of the point from each end of his base-line; these distances he uses as new base-lines for measuring the distances of more distant points and so on. In the case of the Sun, the angle to be measured is what is called the *horizontal parallax* of the Sun; it is the amount by which the Sun at rising or setting is apparently moved—to an observer on the rotating earth—from his true place in the heavens. This angle of parallax is the angle subtended by the radius of the Earth as seen from the Sun and is measured by the ratio of the radius of the Earth to the distance of the Sun. The dimensions of the Earth are known with great accuracy, so that the measurement of the Sun's parallax determines his distance. The angle to be measured is about equal to the diameter of a halfpenny as seen 2,000 ft. away, and it is this small angle that the astronomer endeavours to measure to an accuracy of one part in a thousand.

The Sun is a difficult object for accurate measurement under the best conditions; his large size and the effect of his heat on the instruments used reduce the accuracy of measurement. At rising or setting, when the angle of parallax is largest, the difficulties are greatly increased because we then view the Sun through a great depth of atmosphere, with disturbing effects due to refraction by the atmosphere and to the passage of the Sun's rays near the warm surface of the Earth. If the distance of the Sun could not be determined otherwise than by direct observation of the Sun, it would be a vain hope to expect an accurate answer. But fortunately, this is not necessary because, if the distance of any single object in

the solar system can be measured, the distance of the Sun can be inferred. This is made possible by means of the famous third law governing the motions of the planets, discovered by JOHANN KEPLER (1571–1630) in the year 1618. The law was deduced by Kepler from a study, extending over many years, of the observations by the great Danish astronomer, TYCHO BRAHE (1546–1601), who first introduced accuracy into the measurement of astronomical positions. It was enunciated by Kepler in the following form: the periodic times of any two planets are to each other exactly as the cubes of the square roots of their median distances.

The periodic times taken by the planets to describe their orbits around the Sun can be measured without difficulty and with great accuracy. Hence, by this law of Kepler, their *relative* distances can be inferred. The solar system can therefore be readily drawn to plan; the scale of the plan is fixed as soon as any one distance in it has been measured. The smaller the distance, the more favourable are the circumstances for accurate measurement, because the angle of parallax—from which the distance is inferred—is larger in relation to the errors of observations. From time to time, one or other of the planets in their unending journey round the Sun comes sufficiently near the Earth to enable the Sun's distance to be measured with reasonable accuracy.

But let us first go backwards in time and see what had been learnt about the distance of the Sun before the enunciation by Kepler of his third law gave astronomers this latitude in choice of method of attacking the problem. The first attempt at an estimate of the Sun's distance was made by the Greek astronomer, ARISTARCHUS OF SAMOS, in the third century B.C. In figure 1, S denotes the Sun and M the Moon. E is the position of an observer on the Earth. The Sun illuminates the half of the Moon's surface that faces it, the other half being in darkness. It is obvious that, if the angle SME is a right-angle, the observer at E will see exactly one half of the Moon's face illuminated. The appearance of the Moon is then that known as first quarter. If the distance of the Sun ES were four times the distance of the Moon, the angle SEM would be 75°. The smaller the distance of the Sun, the smaller

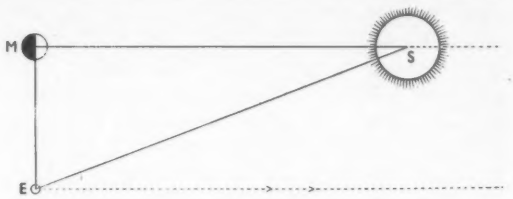


FIGURE 1 – *The method used by Aristarchus to compare the distances of Sun and Moon from Earth. (The sizes and distances are not drawn to scale.)*

this angle will be; if, on the other hand, the distance of the Sun is very great in comparison with the distance of the Moon, the angle MES will be nearly a right-angle. A small error in measuring the angle will then produce a large error in the distance ES. Aristarchus measured the angle MES and obtained 87°; he concluded that the distance of the Sun was nineteen times the distance of the Moon. This distance is about twenty times too small. The true value of the angle MES is 89° 51′ and is so near to 90°—which would place the Sun at an infinite distance—that it was not possible for Aristarchus to determine the distance of the Sun with any accuracy. The method is ingenious and is correct in theory; but in practice it is unreliable, for the boundary between the illuminated and dark portions of the Moon's face is not sharply defined and it is impossible to decide exactly when the face appears half illuminated. Figure 2 shows the appearance of the Moon at first quarter and the ill-defined boundary between the illuminated and dark portions.

In the second century B.C., the Egyptian astronomer PTOLEMY, using observations by Hipparchus of some partial eclipses of the Moon, determined the Moon's distance with fair accuracy. Combining this result with that obtained by Aristarchus he obtained a distance for the Sun about 1,200 times the radius of the Earth, or somewhat less than 5,000,000 miles. This result was accepted without question until the end of the sixteenth century, so great was the authority of the Greek astronomers. At that time Kepler was engaged on his investigations of the observations of the positions of the planets made by Tycho Brahe. In the course of his researches on the motions of Mars, he

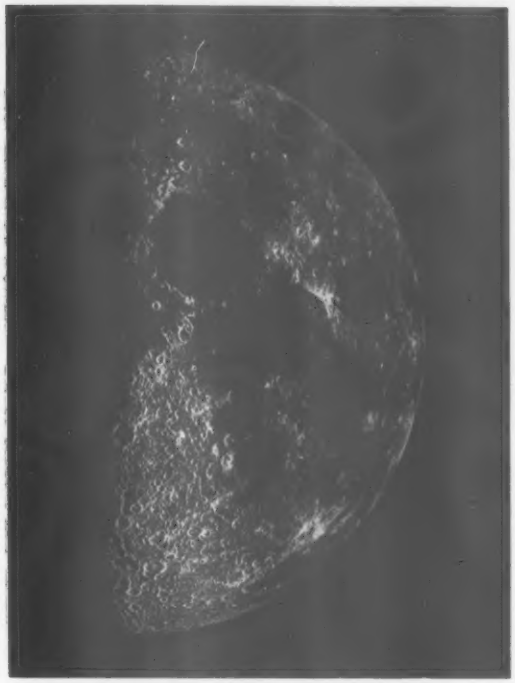


FIGURE 2 – *The Moon at first quarter.*

came to the conclusion that the distance of the Sun must be much greater than had been supposed; he estimated that its distance was between 3,500 and 7,000 times the Earth's radius (i.e. between 14,000,000 and 28,000,000 miles), an estimate which still fell far short of the true distance, though a considerable improvement on Ptolemy's value.

A much better estimate was made by the famous Dutch astronomer CHRISTIAAN HUYGENS (1629–95), not by direct measurement but by an ingenious argument. The apparent sizes of the planets were measured by him with his telescope. Since, as we have already explained, Kepler's third law makes it possible to draw the solar system to scale, Huygens was able to estimate the relative sizes of the planets, with the exception of the Earth. He then assumed that the Earth was intermediate in size between its adjacent planets Venus and Mars, and thereby fixed the scale of the whole solar system. He concluded that the Sun's distance was 25,086 times the Earth's radius, or about 100,000,000 miles. This near approach to the true distance was somewhat fortuitous. The diameter of the Earth is actually rather larger than that of Venus and nearly double that of Mars, so that the assumption made by Huygens was considerably in error; but the poor quality of the early telescopes made the planets appear larger than they are, and this defect, by chance, approximately compensated for his underestimate of the size of the Earth in relation to Venus and Mars.

The two planets which appeared to offer the best scope for measuring the Sun's distance by direct observation were Mars and Venus. The orbit of Mars lies at one point only 34,500,000 miles outside the orbit of the Earth (see figure 5). When the two planets happen to arrive together at the points of nearest approach of their orbits, the best occasion is provided for determining the distance of Mars. At such times Mars is in opposition to the Sun, Mars, the Earth and the Sun being in line and Mars crossing the meridian at midnight. These favourable oppositions occur at intervals of fifteen or seventeen years, in August. Such an occasion occurred in 1672 and was used to provide the first scientific estimate of the Sun's distance. The observations were planned by GIOVANNI DOMENICO CASSINI (1625–1712), the first director of the Paris Observatory, then just completed. An expedition was sent to Cayenne to make observations of Mars, whilst corresponding observations were made at the Paris Observatory; Paris and Cayenne thus formed the ends of a base-line, and from the difference in the direction of Mars as seen from the two places the distance was to be inferred. The result of the observations was to place the Sun at a distance of between 82,000,000 and 91,000,000 miles, with a probable value of 86,000,000 miles—a value that was accepted for about a century. In close agreement with this result was the determination later made by the ABBÉ LACAILLE (1713–62), who made observations of Mars during his visit to the Cape of Good Hope in 1750–52, which he compared with other observations made in Europe.

The orbit of Venus lies inside that of the Earth, so that Venus comes closest to the Earth when she passes between it and the Sun. Her distance from the Earth is then 26,000,000 miles, which is appreciably smaller than the distance of Mars. But Venus then becomes lost to sight

in the rays of the Sun, so that it is only on the somewhat rare occasions when her path lies directly in front of the Sun and she can be seen to transit across the Sun's disk that measurements become possible. Four transits of Venus occur every 243 years, at successive intervals of 8, 105½, 8, and 121½ years. Five transits only have ever been observed, viz. the transits of 4th December, 1639; 6th June, 1761; 3rd June, 1769; 9th December, 1874; and 6th December, 1882. The next two will occur on 8th June, 2004, and 6th June, 2012.

The transit that occurred on 4th December, 1639 (or 24th November, Old Style), was seen by only two people, JEREMIAH HORROX (1619–41), 'the Keats of English astronomy,' and his friend, WILLIAM CRABTREE. Kepler had foretold that Venus would pass over the Sun's disk in 1631, and not again until 1761. The transit of 1631 occurred at night-time in Europe and could not be observed. Horrox recalculated the motion of Venus, found that the tables used by Kepler were in error and concluded that a transit should occur on 24th November, 1639. He was able to make successful observations of the transit at Hoole, in Lancashire, where he was curate, whilst his friend Crabtree, in Manchester, to whom he had confided his prediction, obtained through a break in the clouds one glimpse only of Venus on the Sun's disk.

The use of transits of Venus for determining the distance of the Sun was first pointed out by the celebrated mathematician JAMES GREGORY (1639–75) in his treatise *Optica Promota*, published in 1663. The same suggestion was made independently by EDMUND HALLEY (1656–1742), afterwards the second Astronomer Royal, in his *Catalogus Stellarum Australium*, published in 1679, and the peculiar advantages of this method of finding the Sun's distance were expounded by him in the *Philosophical Transactions of the Royal Society* in 1694 and 1716. As viewed from remote parts of the Earth, the track of Venus across the disk of the Sun will be different, and the times of the beginning and ending of the transit will be different (see figure 3). The differences of path or of time can be translated into differences of space, the distance of Venus relative to that of the Sun being known by Kepler's third law and the distance between the two places of observation being known from the dimensions of the Earth.

FIGURE 3 – *The external and internal contacts of Venus with the Sun, as seen from two different places on the Earth. The times of each of the four contacts are observed.*

Halley emphasized the advantages of basing the determination solely on the observations of the times of beginning and ending of the transit; these could be determined with accuracy, he said, 'without any other instruments than telescopes and good common clocks, and without any other qualifications in the observer than fidelity and diligence, with a little skill in astronomy.'

As the transits of 1761 and 1769 drew near, there were high hopes that this double opportunity of using the method suggested by Halley would very materially reduce the uncertainty in the Sun's distance. Nothing seemed easier than to note the exact instants when the small dark disk of Venus would be just in contact with the edge of the Sun's bright disk, as Venus approached and left the Sun. The principal governments of Europe fitted out expeditions to various parts of the world, observers being scattered to many stations over the face of the Earth. The occasions were amongst the first instances of international co-operation in astronomy, of which there have been many since, from which the science of astronomy has benefited and knowledge has been advanced. It is worthy of note that it was the transit of 1769 that gave CAPTAIN COOK his chance to establish his fame as a navigator. He took a party of observers in the *Endeavour* to Tahiti in the South Seas and, after the transit had been

observed, completed his three-year voyage round the world. Mention may also be made of the ill fortune that befell the French astronomer LE GENTIL. He had intended to observe the transit of 1761 at Pondicherry, but the war between the French and English caused him to arrive too late. He decided to remain there for eight years to make certain of observing the transit of 1769, but clouds at the critical time prevented him from seeing anything. On his eventual return to France he found that during his long absence he had been adjudged legally dead and that all his property had been divided amongst his next-of-kin!

The results of these observations can only be described as disappointing. Unexpected difficulties were encountered in determining the exact instants of contact between the dark disk of Venus and the bright disk of the Sun. Instead of meeting and parting with the clean definiteness that had been looked for, they appeared to cling together, a black spot seeming to form between the edge of Venus and the edge of the Sun, somewhat as a drop of ink clings to a pen which is slowly withdrawn from an inkpot (see figure 4). The results obtained by the various expeditions were very different and discordant, and the uncertainty in the Sun's distance, instead of being reduced to a few hundred thousand miles, as had been confidently expected, remained at several millions. In 1822 ENCKE made a comprehensive discussion of all the observations that had been made at the two transits, endeavouring to co-ordinate the phenomena described by the various observers and to bring order out of confusion. He placed the Sun at a distance of 95,250,000 miles. Of this determination GRANT remarks in his *History of Physical Astronomy* (1852):

> When we consider the ingenuity of the method employed in arriving at this determination, and the refined nature of the process by which it is carried into effect, we cannot refrain from acknowledging it to be one of the noblest triumphs which the human mind has ever achieved in the study of physical science.

But this confidence that all was well was not to remain for long undisturbed. A Danish astronomer, PETER ANDREAS HANSEN (1795–1874), was engaged on the study of the complicated theory of the motion of the Moon, which culminated in some new tables of the

FIGURE 4 – *The appearance of the 'black drop' as the dark disk of Venus transits on to the bright disk of the Sun.*

Moon, published by the British Admiralty in 1857 and for which a grant of £1,000 was made to Hansen by the British Government. In 1854 Hansen announced that the observed motion of the Moon could be brought into accord with theory only if the Sun were appreciably nearer than it was then supposed to be. In the motion of the Moon, there is an effect arising from the fact that the attracting force of the Sun on the Moon is greater on the half of the Moon's orbit that lies towards the Sun than on the other half, because the Moon is nearer to the Sun in the former half than in the latter. This causes a disturbance in the motion of the Moon, with a period of a month, the Moon being more than two minutes behind at first quarter and at last quarter more than two minutes ahead of the position that it would occupy in the absence of this disturbance. The magnitude of the effect obviously depends upon the ratio of the distances of the Sun and Moon from the Earth and provides a means by which the distance of the Sun can be inferred, if observations of the Moon can be made with sufficient accuracy. The complicating factor is that around first quarter the position of the Moon must be determined from observations of one limb and around last quarter from observations of the other limb. Errors will be introduced if the angular diameter of the Moon is not known with very high precision, and the measurement of this diameter is made somewhat uncertain by the irregularities in the Moon's profile, caused by its very mountainous surface and by the fact that the Moon is not quite spherical. In 1858 LEVERRIER, Director of the Paris Observatory, found in this way a distance of 91,000,000 miles. The most exhaustive and complete determination by this method is one that the writer made ten years ago, based on observations of the position of the Moon from 1672 to 1908, which gave a distance of 92,940,000 miles, with an uncertainty either way of about 40,000 miles.

Meanwhile another method by which the distance of the Sun could be estimated had become available. In 1675 OLAUS RÖMER had proved that light does not travel instantaneously, but with finite velocity. He found that the eclipses of Jupiter's satellites invariably occurred later than they should when the Earth was farthest away from Jupiter, and earlier than they should when the Earth was nearest. The difference in time, amounting to about 16½ minutes, represents the time taken by light to travel across the diameter of the Earth's orbit. This made it possible to determine approximately the speed with which light travels. In 1728, the phenomenon known as *aberration* was discovered by JAMES BRADLEY (1692–1762), afterwards Astronomer Royal. Bradley had been puzzled by certain anomalies in his measurements of the positions of stars; the stars seemed to be pushed out of their places, in the direction of the Earth's motion, by a small amount. When he had despaired of being able to account for these anomalies, the explanation came to him suddenly, when he was not in search of it. He had accompanied a party in a pleasure sail upon the River Thames and he noticed that, every time the boat put about, the vane at the masthead shifted, as though the direction of the wind had changed. He commented on this to the boatmen, who told him that the wind had not changed but that it was merely the effect of change of direction of the boat. He at once realised that the anomalies that had been puzzling him in the positions of the stars were due to an exactly analogous cause. Just as the direction in which the wind-vane pointed depended both on the direction of the wind and that of the boat, so the apparent direction in which a star is seen depends upon the motion of the Earth and the finite speed of travel of light. If the Earth stood still, or if light reached us from the stars instantaneously, there would be no 'aberration' in the star's apparent position. The amount by which the stars are displaced depends upon the ratio of the speeds with which the Earth and light travel, which is about one to ten thousand. If, then, the speed of light is known, the speed of the Earth can be deduced. But the speed of the Earth is related to the size of its orbit, for its orbital path is described in one year and, the speed being known, the size of this orbit and, consequently, the distance of the Sun can be inferred.

In Bradley's time there had been no direct measurement of the velocity of light, which could only be ascertained through the imperfect knowledge of the distance of the Sun. The first successful terrestrial measurements of the velocity of light were made by FIZEAU in 1849; since that date many measurements have been made and developments in methods and technique have brought about such an increase in precision that the velocity of light is now known to an accuracy of about one part in 100,000—a remarkable triumph of human ingenuity. It might be thought, therefore, that from the many determinations of the aberration of the stars the distance of the Sun could be found with very high precision. But this method proves to be attended with serious difficulties. The astronomer has always to consider carefully the errors to which his observations are liable, for these errors limit the accuracy of his results. All observations are subject to error to a greater or lesser extent, though, by careful choice of methods and arrangements of the observations, it is frequently possible to eliminate some sources of error and to reduce the effects of others.

The measurement of aberration depends essentially on the comparison of the apparent positions of stars obtained at an interval of about six months, when the Earth is at opposite ends of its orbit. This introduces all sorts of troublesome seasonal effects, caused by differences in climatic conditions, whose nature is very obscure and which are extremely difficult to control. The errors bound up with seasonal causes are amongst the most troublesome in astronomy. Because of the peculiar difficulty in eliminating them, aberration can be determined with greater precision by using the distance of the Sun found by other methods than by direct measurement. What is probably the most accurate determination of the Sun's distance by this method was derived by the writer from special observations at Greenwich, extending over twenty-five years from 1911 to 1936, and gave 92,930,000 miles for the Sun's distance.

By repeated determinations by various methods, the extreme limits for the Sun's distance were slowly narrowed. By 1870 it

could be said with fair certainty that the Sun was not nearer than 91,000,000 miles and not more distant than 96,000,000 miles. The range in possible distance of 5,000,000 miles was still considerable. The transits of 1874 and 1882 were then near at hand; despite the unexpected difficulties experienced in 1761 and 1769, it was confidently expected that a final answer to the question of the Sun's distance would be given by these transits. More than a century had passed, and not in vain; there had been during that time many improvements in instruments, in methods of observation and in general technique. Photography was being developed as an aid to the astronomer and much was hoped from it; though there might be difficulty in co-ordinating and interpreting visual observations, the camera could not lie and would be free from bias.

And so the most intensive scheme of international co-operation that astronomy had yet seen was organized well in advance. The best practical methods of observation were considered by official commissions. The observers were trained beforehand by means of models, designed to reproduce as nearly as possible the expected appearances; the times of ingress and egress recorded by different observers were compared with the true times which, in the case of the model, were known. Thus it was hoped that the habit of each observer, what is known as his 'personal equation,' could be eliminated and used to correct his observations. Special instruments were made to ensure uniformity in equipment and method. England, France, Germany, Italy, Russia, Holland and the United States co-operated and some four score stations were occupied, at a cost of nearly a quarter of a million pounds. Siberia, the Sandwich Islands, Kerguelen and the almost inaccessible St Paul's and Campbell Islands were amongst the places to which expeditions were sent. The weather proved generally favourable; the well-organized arrangements proved equal to the test; the contacts were well observed and many photographs were obtained.

Yet the results proved a great disappointment. The black drop again gave trouble, but not more than was expected. More troublesome was the illumination due to the atmosphere of Venus, which caused the planet to be girdled by a ring of light. So uncertain were the instants of precise contact that observers with identical equipment, and standing a few feet from one another, recorded times that differed by as much as a minute. Photography, on which such high hopes had been based, proved an almost total failure. When all the observations had been co-ordinated, the results discussed, and the photographs measured, the uncertainty in the distance of the Sun remained at about 1,500,000 miles. The great campaign had failed to secure uniformity of judgment on the part of the observers and had contributed little to the precise knowledge of the Sun's distance.

But, undaunted, preparations for the second transit were pushed ahead—with abated enthusiasm, indeed, but with hope that the experience gained in 1874 would be of value. Another occasion would not arise for a century and a quarter, and this one could not be allowed to go by default. Some countries withdrew on the ground that other methods for finding the Sun's distance were more accurate and less costly. The arrangement of the observations was discussed by an international conference in Paris in 1881. Again there were many expeditions, the British parties being scattered from Queensland to Bermuda; visual and photographic observations were once more tried. The results were again disappointing; the distance of the Sun came out at about 92,500,000 miles, but the diversity of results given by the various expeditions and by different methods of discussion showed that no great confidence could be placed in this value. An uncertainty of not more than 100,000 miles had been hoped for; this had certainly not been attained.

But meanwhile other objects more suitable for observation than Mars or Venus had come within the range of celestial trigonometry. In the wide gap between the orbits of Mars and Jupiter there exists a swarm of tiny planets or asteroids circling round the Sun. The first to be discovered was found on the night of 1st January, 1801, by the Sicilian astronomer PIAZZI, and was named by him Ceres, after the tutelary deity of the island. Pallas was discovered in 1802 by OLBERS, Juno by HARDING in 1804, and Vesta by Olbers in 1807. These are the brightest of the asteroids and there were no further discoveries until Astraea was found by HENCKE in 1845. Three more were

found in 1847 and there have been new discoveries every year since, so that about a couple of thousand are now known. Many others, extremely faint and tiny bodies, no doubt remain as yet undiscovered. These tiny planets are possibly the remnants of a former planet that has been disrupted. Most of the asteroids are of little intrinsic interest and the somewhat monotonous work of keeping track of them is carried on because from time to time one of them proves to be of special interest. In 1872 it was suggested by PROFESSOR GALLE of Breslau that some of the asteroids might repay astronomers for much of their disinterested toil in keeping track of them, by aiding their efforts to determine the scale of the solar system. Some of them are sufficiently bright and come near enough to be of use for this purpose, and, being small enough to appear like a star in the telescope, they have a distinct advantage over Mars or Venus, with their large discs. A co-operative scheme for observing the three asteroids Victoria, Iris, and Sappho, arranged by DR (later SIR DAVID) GILL, H.M. Astronomer at the Cape Observatory, and carried out in 1888 and 1889, gave a solar distance of 92,874,000 miles and was undoubtedly the most accurate determination that had been made up to that time.

The 433rd asteroid to be discovered, found on 14th August, 1898, and named Eros, proved to be of singular importance for measuring the Sun's distance. It is a small body, only some fifteen miles in diameter, with an orbit so elliptical that once in thirty years it comes within about 15,000,000 miles of the Earth (see figure 5). One such near approach had by bad luck occurred in 1894, shortly before its discovery. Since then its nearest approaches have been in 1901, when its least distance was somewhat less than 30,000,000 miles, and in 1931, when its least distance was only 16,200,000 miles, affording the most favourable opportunity that has ever occurred for determining the Sun's distance. The observations of Eros were far more numerous in 1931 than in 1901; the circumstances were far more favourable at the latter date because of the nearer approach of Eros to the Earth; the great advances made during the present century in the applications of photography to precise astronomical measurement have made greater accuracy possible in

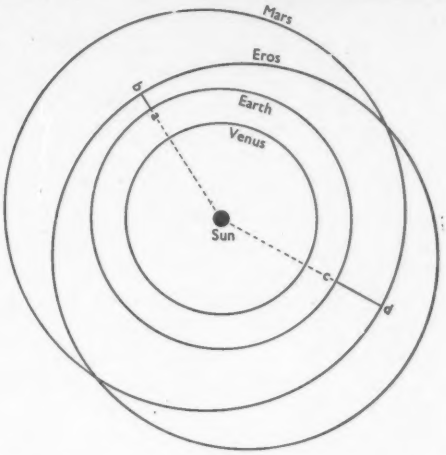


FIGURE 5 – *Orbits of Earth, Mars, Venus, and Eros.* ab *is closest possible approach of Eros to Earth,* cd *is closest possible approach of Mars to Earth.*

the more recent observations. The results derived from the 1931 observations will therefore alone be referred to.

The observations were almost entirely photographic; the method used was to photograph Eros and the surrounding stars on the same plate and then, by careful measurement, to determine its exact position among the stars. As this position differs slightly according to the situation of the observer on the Earth's surface, the comparison of photographs taken at two stations on the Earth's surface enables the relative displacement of Eros to be determined and the distance of the Sun to be inferred. Another method is to take two photographs from the same station, separated in time by a few hours. In the interval, the rotation of the Earth has carried the station some thousands of miles from its former position, so that it becomes virtually equivalent to a second station. A complicating factor is that the observations in the first method will not be exactly simultaneous, whilst in the second method they are separated by some hours, and during the interval both the Earth and Eros have moved somewhat along their orbits round the Sun. The displacement during this interval in the position of Eros as seen from the Earth must be allowed for. This is not a matter of great difficulty when the paths of Eros and the Earth around the Sun are accurately known. Now it

is usually stated that the path of a planet round the Sun is an ellipse. This would be so if there were no other planets. But gravitation is a universal force. It is the gravitational pull of the Sun that compels the Earth to travel around the Sun in an elliptical orbit; but all the while each of the other planets of the solar system is also exerting its gravitational pull on the Earth, which depends on the distance of the other planet from the Earth and is continually changing as the distance changes. The effects of the gradually varying pulls of each of the other planets on the Earth and on Eros must be determined and taken into account when calculating the paths of the Earth and of Eros. This is a long and intricate task.

The positions of all the stars, several thousands in number, which are used as reference points for determining the positions of Eros in the sky, must be derived by special observations. In this lengthy piece of work, thirteen different observatories co-operated, the results being co-ordinated and combined to form a general catalogue of the star positions.

In the observations of Eros itself thirty-two telescopes at twenty-five observatories, situated in England, Belgium, Germany, Italy, Spain, Czechoslovakia, Russia, India, China, Japan, Algeria, South Africa, the United States, Argentina, and Australia, assisted. The writer was in charge of the whole programme. Instructions for the guidance of participating observatories in methods of observation, measurements of the photographs, and reductions of the results were prepared, to ensure uniformity and all possible accuracy. The work of combining and discussing the results from the several thousands of photographs that were obtained has extended over several years and has recently been completed. It is believed that all possible sources of error have been satisfactorily controlled and that the results are accordingly of a high accuracy. The internal consistency of the results is remarkably good: in whatever way the material is divided, rearranged, or grouped, the results are consistent, which confirms the belief that they are free from serious error. The final outcome of this extensive programme of international co-operation is to place the Sun at a distance of 93,005,000 miles, with an uncertainty either way not exceeding 9,000 miles.

One hundred years ago the distance of the Sun was uncertain to one part in twenty; gradually, the uncertainty was narrowed to one part in a hundred; now it has been reduced to one part in a thousand. In the fifth edition of his *Outlines of Astronomy* (1858), SIR JOHN HERSCHEL, referring to a new determination of the Sun's distance, which had brought the Sun nearer by 4,000,000 miles, wrote:

> The superficial reader (one of a class too numerous) may think it strange and discreditable to science to have erred by nearly four millions of miles in estimating the Sun's distance. But such may be reminded that the error in the Sun's parallax, on which the correction turns, corresponds to the apparent breadth of a human hair at 125 ft. or of a sovereign at 8 miles off.

The uncertainty in the newest determination of the Sun's parallax corresponds to the apparent breadth of a human hair at 10 miles or of a halfpenny (for sovereigns are not now available) at 3,250 miles! The goal for which astronomers have so long been striving has at length been reached; the final word has been said on this historic problem for many years to come and the fundamental distance in astronomy has been measured with all the accuracy that is needed.

Agenda

A NEW QUARTERLY

Sir Humphrey Milford announces that he will publish in January 1942 the first number of *Agenda: a Quarterly Journal of Reconstruction*, edited for the London School of Economics and Political Science by Professor G. N. Clark. The purpose of the journal is to make available the results of expert research into the problems of reconstruction on all its sides, domestic and international, social, political, and economic. It will provide clear, fair, and well-informed statements of the facts and problems, written by experts but written both for those who are experts and for those who are not. It will not advocate any policy; but it will be open to articles advocating particular lines of action as well as to objective surveys of facts. The price per number is 6s., annual subscription £1 1s.

The Epigenotype

C. H. WADDINGTON

The adult characteristics of animals, i.e. their phenotypes, must be studied in order to reach conclusions about the genotypes, i.e. the hereditary constitutions which form the basic subject-matter of genetics. But between genotype and phenotype lies a whole complex of development processes, for which Dr Waddington proposes the name 'epigenotype.' He here describes some of the general characteristics of an epigenotype, with special reference to the fruit-fly *Drosophila melanogaster*.

Of all the branches of biology it is genetics, the science of heredity, which has been most successful in finding a way of analysing an animal into representative units, so that its nature can be indicated by a formula, as we represent a chemical compound by its appropriate symbols. Genetics has been able to do this because it studies animals in their simplest form, namely as fertilized eggs, in which all the complexity of the fully developed animal is implicit but not yet present. But knowledge about the nature of the fertilized egg is not derived directly from an examination of eggs; it is deduced from a consideration of the numbers and kinds of adults into which they develop. Thus genetics has to observe the *phenotypes*, the adult characteristics of animals, in order to reach conclusions about the *genotypes*, the hereditary constitutions which are its basic subject-matter.

For the purposes of a study of inheritance, the relation between phenotypes and genotypes can be left comparatively uninvestigated; we need merely to assume that changes in the genotype produce correlated changes in the adult phenotype, but the mechanism of this correlation need not concern us. Yet this question is, from a wider biological point of view, of crucial importance, since it is the kernel of the whole problem of development. Many geneticists have recognized this and attempted to discover the processes involved in the mechanism by which the genes of the genotype bring about phenotypic effects. The first step in such an enterprise is—or rather should be, since it is often omitted by those with an undue respect for the powers of reason—to describe what can be seen of the developmental processes. For enquiries of this kind, the word 'phenogenetics' was coined by HAECKER [3]. The second and more important part of the task is to discover the causal mechanisms at work, and to relate them as far as possible to what experimental embryology has already revealed of the mechanics of development. We might use the name 'epigenetics' for such studies, thus emphasizing their relation to the concepts, so strongly favourable to the classical theory of epigenesis, which have been reached by the experimental

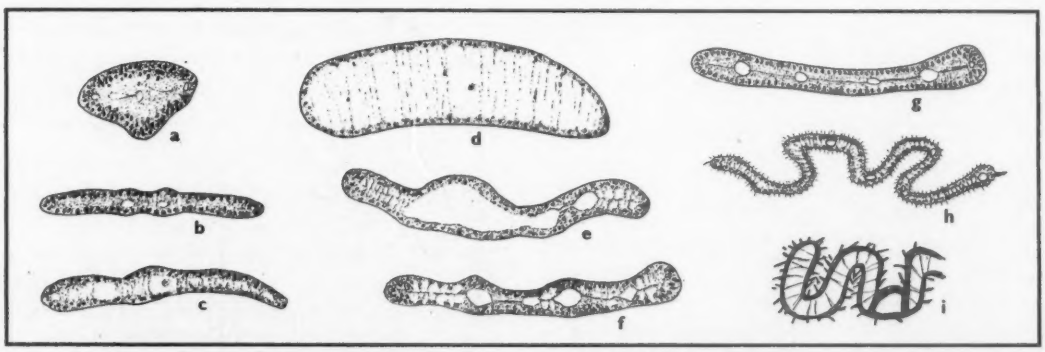


FIGURE 1 – *Diagrammatic drawings of sections of the developing wing in the fruit-fly* Drosophila. *Notice how the wing is at first quite solidly constructed. (Figure* 1 b *is of about the same age as figure* 2 A.) *Then it becomes hollow (figure* 1 d, *which corresponds to figure* 2 B), *contracts again (figures* 1 e, f, g), *and finally becomes folded (figures* 1 h, i).

embryologists. We certainly need to remember that between genotype and phenotype, and connecting them to each other, there lies a whole complex of developmental processes. It is convenient to have a name for this complex: 'epigenotype' seems suitable [5].

We know comparatively little about the general characteristics of an epigenotype. One general feature, however, is that it consists of concatenations of processes linked together in a network, so that a disturbance at an early stage may gradually cause more and more far-reaching abnormalities in many different organs and tissues. Some very beautiful examples of such effects have recently been described by GRÜNEBERG [1], [2], based on mutations in his mouse colony at University College, London. One gene, the 'grey-lethal,' brings about a lack of yellow pigment in the fur, and a failure of the absorption of bone which normally accompanies growth. The latter effect entails a whole host of secondary consequences. Thus the minerals of the body are immobilized in the bones and cannot be used for new growth, so that the teeth are incompletely calcified and unable to masticate solid food. Again, the lack of bone absorption leads to pressure on some nerves, particularly those serving the lower jaw; this presumably gives rise to neuralgic pain, the animals are disinclined to take even liquid nourishment, the starvation affects the thymus gland, and the animals eventually die. Another lethal gene, this time in the rat, brings about even more manifold and at first sight unconnected abnormalities. The first noticeable effect is an abnormality in the development of cartilage, which affects the ribs, and thus the lungs, circulatory organs, and finally the growth-rates of various parts.

Complementary to the study of single genes and the numerous effects which they produce is the study of a single organ and the numerous genes which affect it. Probably the most completely investigated instance is the wing of that favourite genetical object, the fruit-fly *Drosophila melanogaster*. Following preliminary work by AUERBACH, DOBZHANSKY, and GOLDSCHMIDT, I described the developmental actions of some thirty geneloci [6]. It was found that during the first forty-eight hours after the larva enters the pupa, its wings undergo at least fifteen different processes, each of which is affected by some

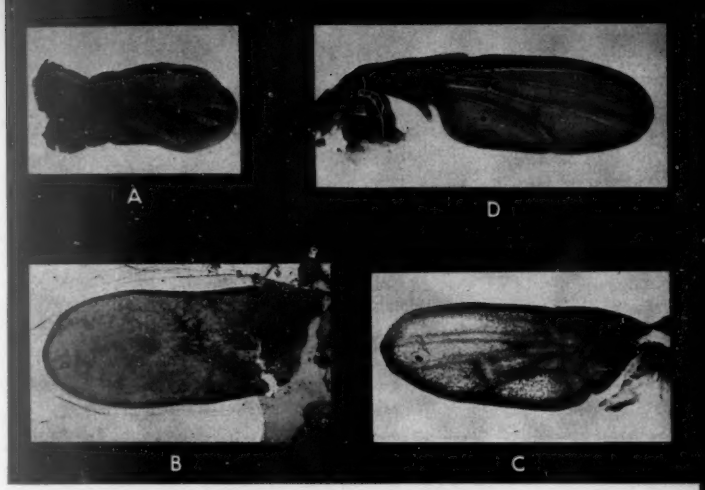
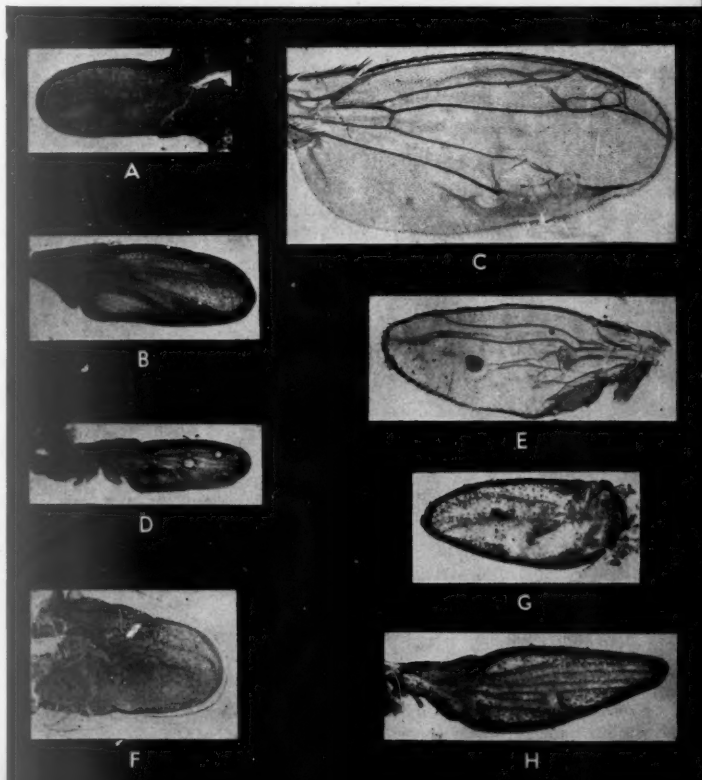


FIGURE 2 – *Four stages in the development of the wing in* Drosophila. *Figure* A *shows the wing shortly after the puparium is formed; in* B *the wing has become inflated, and its venation is obliterated; in* C *and* D *it contracts again and its final venation appears. Just after the stage shown in* D, *the wing becomes folded and remains thus until just after the fly emerges from the pupa.*

FIGURE 3 – *Some genetically controlled abnormalities in the contraction-phase of wing-development in* Drosophila. *Figures* A, B, *and* C *show wings of the mutant race* net *in which there is a partial failure of contraction, which causes the formation of extra veins in some regions. In figures* D *and* E *the failure of contraction is much more complete, and bubbles of fluid are left between the two wing-surfaces, which remain so far apart that in many areas no veins appear (the mutant* bloated). *In figures* F, G, *and* H *the contraction does not fail, but is abnormal, so that a wing of characteristically elongated form is produced (the mutant* blade *in* D. pseudo-obscura).



known gene. We have here, in fact, a concrete example of something which has always been obvious in theory, namely that the genotype is in continual and unremitting control of every phase of development. Genes are not interlopers, which intrude from time to time to upset the orderly course of a process which is essentially independent of them; on the contrary, there are no developmental events which they do not regulate and guide.

The alterations in development produced by genetic changes can be used, as the experimental embryologist uses those which he produces by his operating needle, as a means of analysing the causal mechanisms of development. We find, for instance, that if the two sheets of epithelium which build up a *Drosophila* wing fail to come together as they normally do, the cavity left between them may differentiate into a wing-vein instead of into the normal wing surface. Or, again, we find that if the two epithelia are folded together in an abnormal manner, the position of the wing-veins is determined by the upper surface, and impressed by that surface on to the lower one. These deductions from the 'natural experiments' performed by genes can be checked by experiments of the conventional kind; one can make operations on the developing wings, using fine glass needles and the other micro-surgical instruments of experimental embryology. A considerable series of such operations has been made by LEES [4], who was able to confirm, and in some cases to extend, many of the previous deductions.

For this particular organ there remains very little of that gap between genetics and experimental embryology which has been so frequently lamented as one of the main flaws in the structure of biological theory. As would be expected, many of the general principles of experimental embryology reveal themselves again in the epigenetical analysis. For instance, we are familiar with the fact that there are critical periods in development, such as the time of gastrulation at which the primary organizer is active. Similarly we find that in the development of the wing there are certain periods at which many deviations of development, which had previously seemed of only minor importance, suddenly entail radical and far-reaching consequences. To give a concrete example: the wing is essentially a sac the two surfaces of which are, at one period, forced apart by a considerable pressure of the contained body-fluid, which is later withdrawn so that the two epithelia come together again. The process of contraction is a critical one. Slight irregularities in it are responsible for most of the abnormalities in the development of the wing-veins, and minor deviations in the relative positions of the wings and legs may, by impeding the flow of body-fluid, lead to crippling malformations of those organs.

It would take us too far to attempt to discuss in detail the general characteristics of such epigenetic crises as these. We should find ourselves involved with the same highly complex and little-understood series of problems which confront the experimental embryologist; with the problem of structures of various ranges of size, with the differentiation of cells and of tissues, and with the question of whether differentiation is into sharply contrasted alternatives or into a continuously varying range of products. Without attempting to answer any of these questions here, we may be content to point out that the analysis of the effects of genes has now progressed far enough to become merged with experimental embryology. The two methods of analysis whose *rapprochement* has for so long been no more than a pious hope can now actually and in practice come together in an attack on the still unresolved problems of the epigenotype.

REFERENCES

[1] GRÜNEBERG, H. 'Some New Data on the Grey-lethal Mouse,' *J. Genet.*, 1938, **36**, 153.

[2] *Idem.* 'An Analysis of the "Pleitropic" Effects of a New Lethal Mutation in the Rat,' *Proc. Roy. Soc.*, [B], 1938, **125**, 123.

[3] HAECKER, V. 'Entwicklungsgeschichtliche Eigenschaftsanalyse,' *Phaenogenetik*, Jena.

[4] LEES, A. D. 'Operations on the Pupal Wing of *Drosophila*,' *J. Genet.*, 1941, **42**, 115.

[5] WADDINGTON, C. H. 'Pupal Contraction as an Epigenetic Crisis in *Drosophila*,' *Proc. Zool. Soc. Lond.* (in press).

[6] *Idem.* 'The Genetic Control of Wing Development in *Drosophila*,' *J. Genet.*, 1940, **41**, 75.

Science in the U.S.S.R.

J. G. CROWTHER

Mr J. G. Crowther has an intimate knowledge of Soviet science and scientists, numbering many of the latter among his personal friends. He is thus particularly well qualified to write with authority upon the personalities, ideas, and achievements of the present-day successors of Lomonosov and Mendeléeff. The freshness and vigour of Russian thought are vividly illustrated by Rehbinder's views that science should consciously aim at creating new industries and not be content with improving old ones.

Since the time of PETER THE GREAT, there has always been notable scientific research in Russia. Peter founded the Academy of Sciences in 1724, after the French model. He and his successors depended a good deal for their academicians on importation from abroad. DANIEL BERNOULLI went to St. Petersburg in that year, and shortly afterwards he was followed by LEONHARD EULER. The Academy from its foundation had a very high standard, but from the nature of its origin it was an exotic intellectual ornament rather than a working organ of the state. In the last ten years especially it has been fundamentally reorganized. The principle of the Academy during the first two centuries of its existence was the appointment of men of ability, the more gifted the better, with handsome salaries and light duties. They were then expected to follow the promptings of their inspiration, and embellish history with new knowledge.

The reorganized Academy has quite a different principle. It is intended to be a powerful organ in the advancement of human life. It has the duty of planning scientific activity in the U.S.S.R. so that it will achieve that end most effectively. The Academy was transferred to Moscow so that its directorate would have closer contact with the Government and its institutes would be in a safer strategical location.

The idea of planning is to develop scientific research in a balanced manner, discover and encourage gifted individuals, and lay down lines of investigation consonant with the main interests of the population. For instance, planning is intended to prevent overlapping, and stampedes into fashionable subjects. It will see that there is a proper division of attention between, say, nuclear physics and radiophysics. The periodical reports on the activities of all laboratories help to prevent good men from being overlooked. The co-ordination of the general lines of research with the main interests of the population taps a strong stream of intellectual energy that might have been dissipated in other directions.

The Physico-Technical Institute directed by PROFESSOR A. F. JOFFE at Leningrad is the most famous of its kind in the U.S.S.R. It is one of the group of institutes attached to the Academy of Sciences, and its activities are a part of the Academy's general plan of research. It was started by Joffe in September 1918 in a few rooms of the old Polytechnic Institute. It was moved in 1923 into a handsome building which had been started in 1914 as a home for retired engineers, but never completed.

As the Institute grew, large blocks of new laboratories and machine-shops were added to it. The original staff consisted of JOFFE, SEMENOV, TCHERNITCHEV, DORFMANN, LUKIRSKY, and FRENKEL. The first aim of the Institute was the training of physicists who could become directors of new institutes and foci of new growths of science in distant parts of the country. As a result of this plan, physical institutes have been founded in Kharkov, Dnepropetrovsk, Tomsk, Sverdlovsk, and Samarkand.

This development sprang from Joffe's institute. He is accordingly admired as the founder of modern physics in the U.S.S.R. His sixtieth birthday was celebrated recently by a fine volume in the Academy of Sciences' *Journal of Physics*, which consisted exclusively of a collection of papers by his former pupils.

Professor A. F. Joffe.

Joffe's own researches in recent years have been on semi-conductors. He regards these as substances in which electrons have a moderate degree of freedom, in contrast with insulators in which they have very little, and in metals in which they have a great deal. Their study throws light on the mechanism of the breakdown of insulators, because this happens too suddenly for direct investigation. On the other hand, it cannot be deduced from the properties of metals because the flow of current starts too easily. Another line pursued by Joffe is the strength of solids. It is found that the theoretical strength calculated from Born's theory is several hundred times the observed strength. In his researches in this problem, Joffe and his colleagues observed that the tensile strength of a crystal of rock salt was increased 20 times while immersed in hot water. He attributed this to the removal by solution of cracks on the surface of the crystal, which, according to the theory of Griffith, are a major cause of the observed weakness of glass and other solids.

STEPANOW's suggestion that friction between adjacent planes in a crystal under strain leads to a momentary liquefaction has arisen out of Joffe's work, and has helped to explain why a piece of metal may be suddenly twisted and remain strongly set in its new shape. The metal at the surfaces at the planes of slip is momentarily melted, and then sets quickly while the piece is in its new shape.

The recent investigations of S. E. BRESLER and P. A. PHINOGENOV on microscopic steel balls for bearings is a characteristic product of the Joffe school. It follows from a formula for the deformation of spheres first given by Hertz that small balls may be as effective in bearings as large ones, because there are more of them. Accordingly, mass-production methods of making microscopic steel balls were investigated. Soft carbon steel wire was blown through an electric arc into an atmosphere of nitrogen, producing a 'fog' of steel particles in it. When examined, these were found to be shiny and from a few thousandths to a few tenths of a millimetre in diameter. The larger ones were prolate, and deviated by 5 to 10 per cent. from the spherical; while the smaller ones, owing to the more powerful effect of surface tension, were nearly perfect. Balls about $\frac{1}{10}$ mm. in diameter were separated by sieves. When mixed with oil they reduced friction $2\frac{1}{2}$ times as much as oil used alone.

Perhaps the most remarkable achievement that has come from Joffe's institute is SKOBELTZYN's discovery of the very swift particles in cosmic rays. In 1926 he began a study of the velocity of electrons ejected from radioactive sources by photons, with the aid of a Wilson chamber surrounded by a magnetic field. He published photographs in 1927 of particles which shot through the field with such energy that their curvature could not be detected.

The apparatus with which he secured this fundamental observation was of the most provisional character. The timing of the apparatus was controlled by an old Atwood's machine, which seems to be about the only valuable application of this dreary invention on record.

Skobeltzyn obtained several photographs of positrons, but was not lucky enough to be the first to recognize their nature. He has recently been working on the components of the cosmic radiation, and has argued against the theory of Heisenberg and Euler that the spontaneous disintegration of mesotrons is the mechanism responsible for the formation of the electronic component observed in the lower layers of the atmosphere, because, in his opinion, it fails to

explain the observed divergence between the curves describing the increase in the intensities of the hard and the soft components with height.

One of the most striking figures in Soviet science is N. N. SEMENOV. He is indeed one of the most remarkable men in the world, and is the chief founder of the contemporary theory of chain-reactions. He is a slender, dark-haired man.

SEMENOV and KAPITZA are old friends and fellow-students. In the Leningrad flat of the late MME KAPITZA, the scientist's mother, there used to be a beautiful oil-painting of the pair in discussion over an X-ray tube. It is to be hoped that this historic picture is safe. Semenov started research as a physicist, and studies of the mechanism of the breakdown of insulation, in which a progressive change proceeds through the material, led him to the study of chain-reactions. The classical experiment which accelerated his school on its brilliant career was made by CHARITON and WALTA in 1926. Berthollet had observed in 1797 that phosphorus and oxygen, in spite of their intense attraction for each other at ordinary pressures, do not combine if the pressure of the oxygen exceeds a certain higher limit. Joubert, in 1874, added that the reaction also stops if the pressure falls below a certain lower limit. Chariton and Walta found that if argon were introduced into the vessel, the upper pressure limit was lowered. Semenov showed that the phenomenon could be explained by the theory of chain-reactions. Many more discoveries in the same field have come from his institute. This was founded as a separate laboratory in 1931, an old secondary school building being adapted to the purpose.

Chariton is an old Cavendish student, though his main achievements have been accomplished in chemical physics. He has recently published a characteristic paper on the inability of small charges of explosives to detonate. He made small calibrated glass tubes which were closed at one end, the other end opening out into a funnel about 1 cm. in diameter at the top. These were filled with nitroglycerine, which was left in contact with a priming charge of lead azide at the open end. It was found that if the diameter of the tube was less than 2·08 mm. the detonation did not pass from the wide funnel-shaped part of the tube into the narrower cylindrical part. With a 12 per cent. solution of methyl ether in nitroglycerine, the limit rose to about 3·6 mm. One may suppose that, below a certain diameter, the duration of the scattering of the outer part of the charge is less than the duration of the reaction, so that detonation does not occur.

Professor Peter Kapitza.

The Semenov school has contributed greatly to the strength of the Soviet Union, besides the advancement of knowledge, because its studies on chain-reactions have provided experts on 'knock' in engines, explosives, and other things of practical importance.

Peter Kapitza is well known to many British scientists. The handsome Institute of Physical Problems has been specially built for him in Moscow. He has recently invented a turbine air-liquefier, in which the initial compression of the air is only 5 atmospheres, instead of 200 atmospheres as in the Linde process. This is achieved by taking the energy out of the gas by making it do work in the turbine, instead of depending on the Joule-Thomson effect, which is of secondary magnitude. As the temperature of the air flowing through the turbine, unlike that of the steam in a steam turbine, is low, the working fluid is much more dense, being about five times that of steam at 250° C.

Scientific education: a chemical laboratory at a university centre in Daghestan.

Consequently, the turbine has to be designed to withstand considerable centrifugal forces, like a water-turbine.

Air is compressed by a 50 h.p. compressor, and after passing through water and air coolers is fed at about 7 atmospheres into the turbine. This runs at 40,000 r.p.m., and develops about 4 h.p. The pressure of the air drops 75 per cent. in its passage through the turbine, and if it enters at about — 158° C. it emerges at about — 187° C., the boiling point of oxygen.

The present apparatus produces about 30 kg. of liquid air per hour, and with minor improvements should be as efficient as ordinary high-pressure liquefiers. It is compact, owing to the absence of auxiliary equipment, and it delivers liquid air within the short period of twenty minutes from starting.

Another interesting scientist is P. REHBINDER, who directs research on the chemistry and physics of surfaces in the Physical Institute of the Academy of Sciences in Moscow. He has a burning enthusiasm and energy for research, and original views on the role of science in society. He considers that science should not be the handmaid of industry, but should consciously aim at the creation of new industries. These are vastly more valuable than trifling improvements in conventional manufacturing processes.

Rehbinder's researches include striking investigations on the phenomena of hardness. He has determined the hardness of specimens by deducing the strengths of the molecular fields at their surface from measurements of wettability, and he finds that his results agree with the usual methods of mechanical scratching. His method has the advantage of not damaging the specimen.

He found that thin films are often much harder than solid blocks of the same material. For instance, a thin film of lead on glass may be twice as hard as glass itself, though block glass is thirty times as hard as block lead. In contrast with this, the application of other substances adsorbed by the surface may reduce the hardness.

Rehbinder has recently been examining the effect of the addition of surface-active substances to the mechanical properties of soap-curds. He has added homologues of a number of saturated alcohols, phenol, aniline, etc., to the curds of metallic soaps. He has found that the resistance of the curds to shear is reduced. He believes that the effect is partly analogous to the one he has already described, in which hardness of solids is reduced by adsorbed layers. He thinks that it should be possible to alter the mechanical properties of hard commercial

The Institute of Physical Problems, Moscow.

soaps considerably by adding surface-active substances to them during manufacture and use.

Perhaps the most gifted physicist in the U.S.S.R. is L. I. MANDELSTAMM, whose sixtieth birthday, like Joffe's, was recently celebrated by a special volume in the *Journal of Physics* of papers by his pupils. He works in Moscow University and the Physical Institute of the Academy. Mandelstamm is modest, retiring, and self-critical. He does not like lecturing, and is cautious in publication. He discovered, in collaboration with Landsberg, the effect which now bears the name of Raman, in February 1928. While they were checking their results, Raman independently discovered the same effect and promptly published his observations in March 1928. This is only part of Mandelstamm's work. He has created a school of research in non-linear oscillations which is of the highest importance in radiophysics and aerodynamics, and helps to explain the strength of the Soviet Union in these fields.

The theory of non-linear oscillations was founded a century ago in connection with planetary perturbations, and was developed by Poincaré: Mandelstamm began the application of the theory of physical problems about fifteen years ago. Besides leading to improvements in radio circuits, it has inspired the invention of a new type of dynamo. It consists of a condenser which is placed in a circuit containing a self-inductance. The plates of the condenser are shaken by a mechanical motor, so that the distance between them is always changing. This varies the capacity of the condenser and produces a current in the circuit whose period is one half that of the mechanical oscillator. Thus the energy of the mechanical oscillator is converted into a high-voltage electric current.

Such are a few of the Soviet scientists and their researches. There are hundreds of others, in very different branches of science. They are an example of the quality and energy of the scientific workers in the U.S.S.R.

British scientific genius

An illustrated review of *British Scientists*[1], by Sir Richard Gregory, Bt., F.R.S., a new volume in the series *Britain in Pictures*, published by William Collins of London.

Amid the strife of faction or the din of battle it is not always easy to preserve a right perspective of events. Few educated Parisians under the Terror would have regarded Lavoisier's overthrow of phlogiston as more pregnant of effect upon the future of civilization than the execution of Louis XVI and Marie Antoinette, and no contemporary could have justly gauged the relative importance of two events of 1812—the retreat of Napoleon from Moscow and the discovery of iodine by Bernard Courtois. We live in even more disturbed and disturbing times, so that it is well for us to take stock of our judgments and examine them with a poised objectivity.

If we do this, we can hardly avoid the conclusion that, though scientific discoveries have often been—and are still being—put to shameful use, science has immeasurably improved the lot of man and possesses unlimited potentiality for further good in the future. Advance in civilization, indeed, is advance in science; and when, as at present, civilization is threatened, the threat is implied no less to science. This is made clear, if illustration were needed, by the wholesale reduction in numbers of students and teaching staff effected by the Nazis in German university laboratories, scientific institutes, and other educational establishments where science is taught.

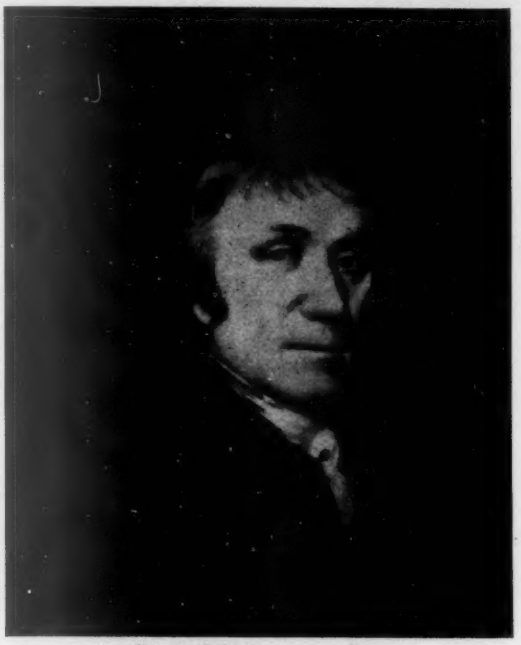
Yet, though civilization is the gift of scientists to mankind, they have often little honour in their own or any other country. The Englishman to whom the names of Drake, Hawkins, Frobisher, Cromwell, Nelson, Wellington, Haig, Jellicoe, and Beatty are familiar and celebrated

[1]Pp. 48, with 12 plates in colour and 19 illustrations in black and white. William Collins, London. 1941. 3s. 6d.

Sir Isaac Newton, 1642-1717.
Oil painting attributed to Sir James Thornhill.

Hon. Robert Boyle, 1627-91.
Engraving by B. Baron after the painting by T. Kerseboom.
By courtesy of the Institute of Chemistry.

Sir Humphry Davy, 1778-1829.
Oil painting by Sir Thomas Lawrence.
By courtesy of the Royal Society.



Joseph Priestley, 1733-1804.
Chalk drawing by Ellen Sharples.
By courtesy of the National Portrait Gallery.

Michael Faraday, 1791-1867.
Oil painting by A. Blakeley.
By courtesy of the Royal Society.

James Clerk Maxwell, 1831-79.
Engraving by G. J. Stodart.
By courtesy of the Cavendish Laboratory.

would usually find it difficult to recall an equal number of his country's men of science. It is, nevertheless, indisputably true that these soldiers and sailors, great as they were, signify less in the grand progress of humanity than Boyle, Newton, Cavendish, Dalton, Davy, Faraday, Darwin, Huxley, and J. J. Thomson.

In his small but delightful book *British Scientists* Sir Richard Gregory sets out to tell the public something of their scientific countrymen from the days of Roger Bacon to the early years of the present century. He rightly points out that, though science is an international study, 'British scientists have taken a leading part' in its development, 'and their works occupy a prominent place in the records of achievement of most branches of modern science. Their contributions are particularly distinguished by originality of conception in combination with experimental inquiry. It is scarcely too much to say that British scientific genius is prominently displayed in the discovery of the most significant and universal principles in Nature, as well as in the field of pioneer mechanical invention.'

Lord Rayleigh, 1842-1919.
Oil painting by Sir Philip Burne-Jones.

Sir Richard begins his story with Roger Bacon—a very appropriate starting-point, since this medieval friar was one of the first to insist upon the value of experiment in scientific investigation. The experimental method seems so obvious to us today that we are inclined to regard it as having always been so; in actual fact it was of very slow growth and did not reach full maturity until the seventeenth century. Before the time of Boyle (1627-91), the most celebrated English disciple of Bacon was William Gilbert, who applied the experimental method in investigating the properties of magnets, invented the word electricity, and was one of the earliest advocates in England of the views of Copernicus. With Newton (1642-1717), British science burst into full efflorescence, entering upon a period of brilliance that has continued until the present day and shows no signs of diminishing intensity but rather the contrary.

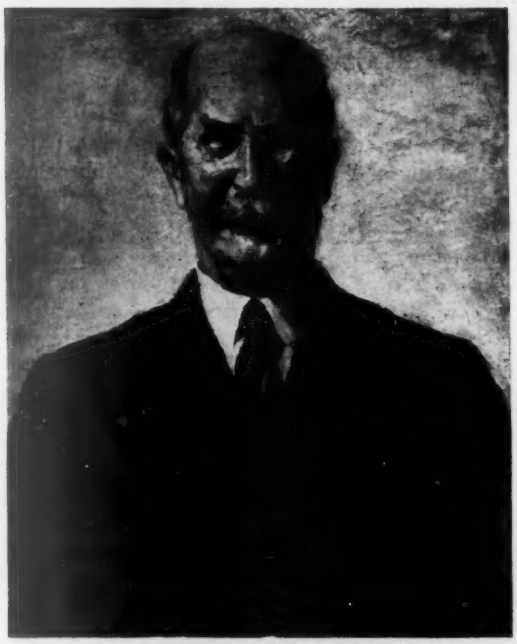
A powerful factor in the advance of science is represented by such bodies and foci as the Royal Society and the Royal Institution, and Sir Richard gives outlines of their history and work. He also has sections on such topics as the steam engine, the locomotive, the dynamo and the turbine, all of which are British inventions; on electromagnetic waves, where the pioneer work was carried out by Faraday and Clerk Maxwell; on the structure of atoms, another field in which the fundamental researches were made in Great Britain; and on several further aspects of scientific progress due largely to British scientists. Even the most indifferent layman should be stirred to pride in British scientific genius when he reads these pages —few in number, but each recording some discovery of vital importance to human welfare.

The admirable quality of the text is equalled by the very fine collection of portraits, upon which both Sir Richard and his publishers are to be congratulated—the author for his skill in selection and the publishers for the excellent way in which the portraits are reproduced. By kind permission of Messrs. Collins, several of the portraits are given again here; but it should be pointed out that, in the book itself, no fewer than twelve of the plates are in colour.

Charles Darwin, 1809-82.
Oil painting by John Collier.

Sir Joseph Thomson, 1856-1940.
Oil painting by Arthur Hacker.

Lord Rutherford, 1871-1937.
Drawing by Francis Dodd.
By courtesy of the Trustees of the Fitzwilliam Museum.



Sir William Bragg, 1862-
Oil painting by Sir William Nicholson.
By courtesy of the Artist and the Royal Institution.

The manufacture and use of vitamins

A. L. BACHARACH

The subject of vitamins is one of those scientific topics which from time to time attract popular attention and form 'news.' Unfortunately the average British journalist seems to imagine that work on vitamins has been carried out in 'every country but his own.' Mr Bacharach, in reviewing the vitamin problem, shows that Britain has played a leading part in its solution.

Much has been done in Great Britain—and is still being done—in the manufacture of vitamin concentrates and pure vitamins and in presenting them to the public, either by way of 'fortifying' foods or in medicinal form.

The discovery that Vitamin D, which prevents rickets in young children and an analogous disease of the bones in adults, could be produced by the action of ultra-violet rays on certain fats was made almost simultaneously by STEENBOCK and the late ALFRED HESS in the United States. It was not long before the actual compound concerned, the pro-vitamin as it is called, was identified; in this work British scientists and a German group working at Göttingen also played a dominating part. The actual isolation of pure crystalline calciferol, the name given to the vitamin produced by irradiating vegetable fats or their pro-vitamin, was in fact accomplished almost simultaneously in 1931 and 1932 by a group of workers at the National Institute for Medical Research and by PROFESSOR WINDAUS' team, and it is pleasant to recall that a considerable interchange of information took place between these 'rival' groups. Crude concentrates of Vitamin D had already been made available to the public by at least two firms of British manufacturers. It must be emphasized that the term 'crude' is used in a relative sense only; even these crude concentrates had an extremely high antirachitic activity, many hundreds of times that of the best cod-liver oil. However, within two years of the isolation of calciferol, oil solutions, tablets and other medical preparations of the pure crystalline vitamin were being manufactured and marketed by at least four firms in this country. To this day, as far as is known, England and Germany are the only two countries in the world where the manufacture of calciferol has reached a relatively large scale.

Meanwhile, the margarine manufacturers had been seeking methods of improving a food on which nutritional experts had been inclined to look somewhat coldly. The chief respect in which margarine was inferior to butter, apart from palatability, was in its complete freedom from both Vitamin D and the equally important Vitamin A. Certain brands of margarine were fortified with concentrates of both these vitamins; as soon as calciferol became available on a commercial scale, the margarine manufacturers replaced the cruder concentrate with this pure crystalline vitamin and increased the number of brands to which it was added. The compulsory 'vitaminization' of margarine that has taken place since the war has merely been an extension to the whole margarine output of a practice already in partial operation in this country and many countries abroad. It may be added that although 1 gram of calciferol is sufficient to fortify 40 tons of margarine, the requirements for calciferol (and for the necessary quantity of Vitamin A concentrates) reach very high levels. Without access to figures that are not easily available outside Government Departments, it is not possible closely to compute the quantities concerned. If, however, we assume that 4 oz. of vitaminized margarine are eaten every week by every member of the population, which can be taken as 40,000,000 (and

this is probably a considerable underestimate on both points), it can easily be calculated that the weekly requirements of calciferol are 120 grams, i.e. approximately 1 lb. a month. To this must be added production for export, as well as for use in medicinal products here and abroad.

Those who can recall the excitement with which the first few almost microscopic crystals of calciferol were inspected by enthusiastic chemists, no longer than ten years ago, are in the best position to realize what an achievement this represents. The manufacture of calciferol is by no means a simple or straightforward operation, but one that involves scrupulous care and high manufacturing skill at every stage. Furthermore, the fortification of the margarine has itself to be rigorously controlled and finally confirmed by difficult and complicated biological tests.

A similar story could be told of the gradual improvement in preparing Vitamin A concentrates. These, unlike calciferol, are not made artificially by the conversion of an inactive provitamin into the required compound, but are prepared by the concentration of the vitamin from rich natural sources, in particular fish-liver oils. Hundreds of thousands of gallons of these oils have been through the British manufacturing plants under the control of British chemists, who have succeeded in preparing concentrates of such potency that they can be incorporated in margarine without in any way affecting its taste or odour. To this result, again, the work of scientists in many countries has contributed, that of British chemists, biochemists, physical chemists, organic chemists, and others being by no means least.

It is not possible here to consider, even briefly, the similar history that lies behind the present-day manufacture of other vitamins. Vitamin C (ascorbic acid), necessary for the prevention of scurvy; Vitamin B_1 (aneurin), the anti-beriberi vitamin; nicotinic acid, the pellagra-preventing factor; Vitamin E (tocopherol), an essential for normal reproduction; and also a compound closely related to Vitamin K and identical in physiological properties, necessary for the normal clotting of blood—all these have been isolated from natural sources, have had their chemical nature precisely determined, have been synthesized in the laboratory and are today being made in British factories.

It is perhaps desirable here to say a few words about the oft-recurring controversy as to the superiority of 'natural' over 'artificial' vitamins. This controversy does not exist for the chemist, who recognizes each vitamin as a separate chemical individual, having properties that depend upon its chemical structure and not on its origin or method of manufacture. Nevertheless, many people, unfortunately including some physicians, still seem to have a curious semi-mystical belief in 'nature' and her products. Why something made by man, himself a product of nature, should be held to be unnatural, is a little difficult to understand, but it is not necessary to appeal to the criteria of logic or to trespass in the dangerous realms of metaphysics in order to be clear on this matter. It has arisen in the past, long before the very existence of vitamins was suspected, and it will doubtless arise again. When salicylic acid was first made from coal-tar, there were many who thought that it did not, and could not, have the virtues of salicylic acid prepared from the wintergreen plant. Today no doctor dreams of insisting upon 'natural' salicylic acid or aspirin made from natural salicylic acid. By the same token, the Vitamin B_1 produced in ever-increasing quantities, both for medicinal use and for the fortification of white flour, is identical in composition and properties with the minute amounts that were first isolated from yeast, wheat-germ, or rice polishings in laboratories, in several parts of the world.

The confusion, however, has a partial explanation, though little justification, in the nature of deficiency diseases. These generally arise in populations living at a very low level of subsistence, and it happens more frequently than not that a deficiency disease is due to shortage or absence of several factors from the diet. When these deficiency diseases are cured by natural products, by food-substances like liver or yeast or orange-juice, for example, it is possible—indeed probable—that more than one deficiency is being relieved by the treatment. If now the physician has laid undue emphasis on a single deficiency, and proceeds to administer one vitamin only, he may not obtain the same success as is possible with the 'natural' product. But this is not because the natural vitamin differs from the artificial one. It would make not the slightest difference to

his result if he used Vitamin C laboriously isolated from lemon-juice or black-currants, or Vitamin C made in the factory by a series of complex and beautiful reactions from glucose as the starting material. Either he would obtain a cure with the vitamin, whatever its origin, or he would not.

This brings one immediately to the question of vitamin 'pills,' a somewhat unworthy description of the elegant tablets and capsules now available to the medical profession and the general public in innumerable pharmacies throughout this and every other country. On the matter of multivitamin treatment, there are different schools of thought. Most British manufacturers have preferred to concentrate on the preparation of products containing one, or at the most two, vitamins in known and specific quantities, and to leave the medical practitioner to decide if more than one of these products should be administered to a particular patient. Such a policy has the advantage of giving flexibility of dosage, to suit different conditions, and in the opinion of many people it is the desirable policy for peace-time. It is unfortunately true that the price of such products, because of the large amount of research and skill that has gone into their production, is such as to put them out of reach of the majority of the population, even in relatively wealthy countries, except when there is actual illness and they are to be taken specifically as medicine. In ordinary times, people who could most benefit from such products as regular supplements to their food are the very people who can least afford them. Alternatively, to market such products at a price within the reach of the less fortunately circumstanced would be possible only if they included such relatively small amounts of the different vitamins as to make them practically valueless for the purpose intended.

Conditions in war-time have somewhat altered the picture. There is more to be said today for encouraging people to supplement their diets with adequate amounts of concentrated or pure vitamins than there was even in peace-time, but the economic problem remains. Such a practice could, in fact, be widespread only if the products were made available through suitable Governmental action, and even then considerable caution would need to be exercised in the claims made for the practice. At the present time we have much reasonably accurate knowledge about human requirements for most of those vitamins that have been made available in pure form and in large quantities. But the advance of knowledge and research, still continuing in this country, makes it highly probable that other vitamins yet remain to be isolated, isolation doubtless to be followed in due course by establishment of their chemical constitution and of methods of synthesizing them. Indeed, we know today of three or four substances, occurring in some foods and essential for the health of certain species of animals, that are very likely also essential to the health of man; they have, in fact, been synthesized, but ignorance of human requirements for these compounds has not yet made it worth while to begin manufacturing them on an extensive scale.

If, however, these known substances, and others as yet unknown, are essential to health, it follows that no multivitamin 'pill' that can at present be devised will adequately replace a mixed all-round diet of a kind known to be necessary for optimum nutrition. The widespread distribution of multivitamin products could certainly prevent the occurrence of known deficiency diseases—scurvy, rickets, beriberi, pellagra—as well as night-blindness and other manifestations of Vitamin A deficiency. It might, therefore, be a measure of far-seeing intelligence to make available to every man, woman, and child in Great Britain a product containing a reasonably adequate daily dose of Vitamins A, B_1, C, and D and nicotinic acid. But this could be done without risk only if at the same time propaganda, education, and the necessary practical steps for improving dietary habits, even on the basis of the foods available under war conditions, were maintained and intensified.

Prospects for soil conservation

G. V. JACKS

During the last few years, the world has awoken to the dangers threatening it from soil exhaustion caused by short-sighted methods of agriculture. Much has been written on the subject, and at least one country, the United States, has taken active steps to prevent the impending catastrophe. But in many parts of the British Empire and elsewhere the economic incentive to exploit the soil remains too great to be resisted, so that a problem of great urgency awaits solution. Mr G. V. Jacks, Deputy Director of the Imperial Bureau of Soil Science at the world-famed Rothamsted Experimental Agricultural Station, here describes the whole matter with a lucidity and a freedom from technicalities that will make it clear to every reader.

During the last century, wherever new land has been opened up for settlement, there have been practised kinds of agriculture which have resulted in a depletion of the natural fertility of the soil. Soil-depleting agriculture is almost invariably the rule when land is first settled, and there is nothing particularly blameworthy about this latest, world-wide appearance of it. But a remarkable feature of recent settlements has been the rapidity with which symptoms of soil exhaustion have appeared after a country has been opened up. The first symptoms are falling yields, which nobody bothers much about, because they are expected. A later and quite unexpected phase of soil exhaustion has been not a further gradual diminution of yield, but the more or less complete disappearance of the soil itself. It is practically impossible to reduce the crop-producing power of soil to zero however exhaustively it is cultivated, but it has been found that long before complete exhaustion is approached, the soil loses its capacity for remaining in place. A fertile soil, wherever it is formed, has many of the properties of a sponge—it can absorb quantities of water, and possesses considerable internal cohesion. An infertile or exhausted soil loses this water-absorbing capacity and cohesiveness, and breaks down to a mass of separate particles, in which condition it is very readily washed away by water or blown away by wind.

In this way, as a result of the depletion of a mere fraction of the total soil fertility, enormous areas, mainly in North America, Africa, and Australia, have been denuded of soil and are now to all intents and purposes barren wastes. The current wastage of land through this so-called soil erosion is not immediately serious for the world as a whole, since there is still plenty of good land for everybody, but it is becoming serious in certain countries, notably the United States and territories in South and East Africa. It was stated a few years ago that at the then rate of erosion the United States would be incapable of organized existence by the end of the century. For much of Africa, where erosion is a more rapid process, the end of the century would be an optimistically distant date for the end of human dominion over the land.

Summary figures of a national survey made in the United States in 1934 illustrate the extent of the damage done by soil erosion, mainly within the last forty years. Of the total land area 14 per cent. had lost three quarters to all of the soil, 42 per cent. had lost one quarter to three quarters of the soil, and 30 per cent. (much of it unsuitable for agriculture) was uneroded. Apart from the loss of productive soil, incalculable damage has been done by chronic flooding of the main rivers, progressive desiccation of the land, and the profound disturbances to the normal regime of ground waters that are produced by the disappearance of the absorbent surface soil and adversely affect agriculture even where no erosion has occurred. The process of erosion, once started, proceeds under its own acceleration in ever-widening circles. It works insidiously, striking

at the base of social existence while leaving the main superstructure of society untouched. For this reason it never has been, and probably never will be, taken in hand by the community as a whole until it has reached an advanced stage at which the threat to the superstructure becomes apparent.

The cause of soil erosion is often given as the destruction of the natural vegetation which normally affords the soil adequate protection from the erosive action of rain and wind. This is correct up to a point, but there is no reason why the destruction of the natural vegetation, whether forest or grassland, should necessarily be harmful. All agriculture involves such destruction, and it stands to reason that no permanent agriculture is possible where the soil is progressively deteriorating. The real cause of erosion is the practice of an agriculture which does not take full account of the natural limitations of the environment and causes soil exhaustion, which is the invariable precursor of soil erosion. Soil in a high state of fertility rarely erodes, even when stripped of vegetation, and the only certain cure for soil erosion is to utilize the land in a manner which maintains, and preferably increases, its fertility. Such a type of land utilization is general in the highly farmed countries of Western Europe, where, despite prolonged and intensive agriculture, the soils are probably now capable of greater and more sustained production than at any previous time. The agriculture of the Middle Ages was, like the present-day agriculture of much of the New World, soil-exhausting, and might ultimately have caused widespread erosion had it not been put on an entirely new basis by the agricultural revolutions of the seventeenth and eighteenth centuries. These resulted in a type of agriculture that, so far as the maintenance of soil fertility was concerned, made the optimal use of the natural qualities of the environment.

In the eroding countries of the New World a comparable harmony between agriculture and the environment does not exist; erosion is, indeed, the most common physical symptom of an absence of such harmony. In these countries the evolution of agriculture has been governed by opportunism—by the potentialities rather than by the limitations of the environment. The latter, however, are now making themselves felt. Nature imposes her own harsh discipline on those—whether man, animal or plant—who cannot or will not play their allotted part in preserving the biotic equilibrium which assures the continuing fertility of the earth. Elimination is the invariable rule in such cases, and soil erosion is a very effective way of eliminating man. Agriculture must either develop into a process that increases the fertility of the soil, or cease altogether. The factors, chief among which is the climate, that determine how the soil must be cultivated so as to increase its fertility are still largely outside human control.

On the other hand, the factor which determines how the land actually is utilized is primarily economic. In general, men will always cultivate the land in the way that gives them the greatest economic advantage, and soil-exhausting agriculture, which implies drawing on the existing fertility reserves, tends to be easier and more immediately profitable than soil-conserving agriculture, which implies investing something in the land to pay a dividend at a later date. Consequently, although the measures required to stop erosion and build up soil fertility are simple and understood everywhere, they are not applied on a scale commensurate with the task unless and until the economic conditions of a country make it more profitable to conserve than to exhaust the soil. The first essential step in the soil-conserving agricultural revolution in Britain—the enclosure and pasturing of exhausted arable land—was promoted by the prosperity of the wool trade and the contemporary depression of the grain trade. In recent years one country—the United States—has apparently turned the corner from soil-exhausting to soil-conserving agriculture, not from a recognition of the fatal consequences of continuing soil erosion, but as a result of the disappearance of the export market for soil-exhausting crops. The Agricultural Adjustment Administration was set up to reduce the acreage of these unsaleable crops; it has survived many vicissitudes to become a powerful agent in encouraging the cultivation, in their place, of soil-conserving crops. American economy is developing along lines which are making it more profitable to make than to destroy soil fertility. Provided future developments are in the same direction, the problem of soil erosion will solve itself.

These developments are towards a more self-sufficient economy than has prevailed hitherto. As agriculture becomes self-sufficient, the limitations of the natural environment assume a much greater importance than they possess in a period of expansion. The countryside begins to take on an appearance dictated by the qualities of the land, and human society a form which harmonizes with the environment. Permanent agriculture is established and civilization has a chance to develop on a secure foundation. Already we can trace in the United States the emergence of new cultural patterns representing the landscapes of permanent, soil-conserving agriculture. Associated with these patterns there is emerging also a new form of society that is based on the community as the ultimate social unit and rejects the 'rugged individualism' which was such a marked feature of the pioneering era. It has been proved beyond doubt that the individual, working by and for himself and in open competition with his fellows, is incapable of preserving the fertility of the prairie environment; sooner or later he must destroy the soil in the struggle to maintain his position in society, whereas a co-operating community of farmers acts spontaneously in such a way as to preserve its social base, the land. Unstinted co-operation between occupiers of land is now recognized as so vital to the success of any scheme for soil conservation that the Federal authorities refuse their essential assistance unless co-operation is assured. What co-operation means at the present time—a very embryonic stage in the evolution of permanent agriculture—is that while the owner retains full legal title to his land the community of which he is a member decides how he shall utilize it; and unless the community decides that the land shall be worked so as to conserve its fertility, the very existence of the community itself is threatened.

The necessary requisites for the accomplishment of soil conservation in an eroding region are thus, firstly, an economic system under which it is more profitable to make than to destroy soil fertility, and secondly and complementarily, a form of society that can work the economic system. Given these—they are complex functions of the environment—permanent, soil-conserving agriculture follows automatically. There is nothing particularly difficult about the technique of permanent agriculture, but the conditions which make its application generally acceptable must obtain. In Britain they have obtained for so long that soil conservation has become the primary concern of agriculture, and not all the outcry for super-efficient farming can shift the deeply rooted instinct of the community to preserve the soil intact. In the United States favourable conditions, first created by the world-wide economic depression, are just beginning to appear. Thanks partly to the neglect of British agriculture and partly to their financial indebtedness to the Mother Country, the main agricultural regions of the British Empire retained their overseas market after the agricultural depression, and have continued to export large quantities of the produce and fertility of the soil. The economic incentive to exploit the soil has been too great to be resisted.

It is doubtful indeed whether agriculture can ever become conservative so long as the farmer is concerned with adapting his practices more to the requirements of a foreign market than to the limitations on land utilization imposed by Nature. In other words, a large measure of self-sufficiency is indispensable to the establishment of permanent agriculture. This is what one would expect on theoretical grounds, and it is fully borne out by recent experience. The United States owes the salvation of its soil to the disastrous breakdown of international trade; other eroding countries may survive to thank the grim economic aftermath of the war for affording the opportunity to reorganize their agriculture on a stable and enduring foundation. It is at least certain that a heavy price is owing for soil exhaustion, but the sooner payment is enforced the less onerous it will be.

Vignette of a master and his masterpiece

JOHN READ

James Young, founder of the Scottish shale oil industry, formed an outstanding collection of rare and early books and manuscripts on alchemy and chemistry; and in John Ferguson he found an excellent and erudite cataloguer.

It is a sad reflection to students of historical science that Ferguson's *Bibliotheca Chemica* is unknown, even by name, to the great majority of chemists and chemical students of the present day. The two handsome volumes are to be seen in all our great libraries, but their pages are too often uncut. Accomplished chemists of the present generation have been known to ask wonderingly: 'What *is* this *Bibliotheca Chemica* you mentioned, and who *was* Ferguson?'

James Young.

Bibliotheca Chemica is the great master-work of alchemical bibliography, and JOHN FERGUSON was in the first flight of historians of science. *Bibliotheca Chemica*, it is true, bears the somewhat misleading sub-title: 'A catalogue of the alchemical, chemical and pharmaceutical books in the collection of the late James Young of Kelly and Durris, Esq., LL.D., F.R.S., F.R.S.E.' Far from being a mere catalogue, this monumental work, issued at Glasgow in 1906 in two closely printed volumes containing more than a thousand quarto pages, is the most valuable of all publications dealing with the bibliography, the history, and the leading figures of alchemy and early chemistry. It consists of an alphabetical arrangement, under authors' names and titles, of the extensive Young collection, with bibliographical details of each work, biographical notices of the writers, and exhaustive lists of references in chronological sequence. Its scope and accuracy are a continual source of wonderment to all who have had occasion to gain an intimate acquaintance with its contents. Not the least remarkable fact about a work so esoteric in character is its close connection with modern chemical industry.

Dr James Young (1811–83) studied chemistry at Anderson's College, Glasgow, under the famous Thomas Graham, and later founded the shale oil industry in Scotland. About 1850, following the example of his friend, Dr Angus Smith, James Young began to collect works of interest in the history of alchemy and chemistry. In this pursuit he was aided materially by Dr John Ferguson (1837–1916), Professor of Chemistry in the University of Glasgow from 1874 to 1915. The resulting collection was eventually bequeathed to the Chair of Technical Chemistry which Young had founded in Anderson's College; this institution developed into the Royal Technical College, where the Young Collection is now kept. 'The founder of a great industry, . . . engrossed in business transactions,' wrote Ferguson, 'was hardly the person whom one would have expected to undertake the formation of a library of old, neglected, and out-of-the-way books on the practically extinct topic of alchemy; yet Dr Young did this because he perceived that as alchemy happened to be one of the phases which chemistry formerly presented, a survey of it is indispensable for completing the history of the whole science.'

Altogether, Young collected some 1,350 or 1,400 separate items, including many of the

'omnibus' volumes, such as Manget's *Bibliotheca*, which are so characteristic of alchemical literature. As Ferguson pointed out, many of the books represented in the collection had become almost extinct by the end of the nineteenth century. 'It is fortunate,' he wrote, 'that some of these exceedingly rare treatises in English were secured before it was too late.' The collection is particularly rich in German alchemical writings of the seventeenth and eighteenth centuries.

The Ferguson Collection, which is in some respects still more extensive than the Young Collection, is preserved in the Library of the University of Glasgow. Professor John Ferguson was no less successful as a book-hunter than as a bibliographer: 'he, single-handed, challenged competition with institutions like the British Museum and the Bibliothèque Nationale,' remarks Professor T. S. Patterson, who mentions, as a specific example, that of Beguin's *Tyrocinium Chymicum;* in its various forms the Bodleian Library and the Young Collection have eight copies each, the British Museum thirteen copies, the Bibliothèque Nationale seventeen copies, and the Ferguson Collection no fewer than thirty-one copies, representing twenty-three editions.

John Ferguson.

The same writer has given some interesting glimpses of Ferguson's personality. Like other bibliophiles, he was very reluctant to destroy any kind of printed matter, and his literary accumulations threatened to monopolize his house. Publications expelled him from his study and overflowed into his dining-room, obliging him to use his dining-room table for the examination and annotation of his latest acquisitions in his neat and delicate handwriting. The literary inundation first reached

> the sofa which stood between the two windows, and when that article of furniture had become hopeless as a place of rest even for more literature . . . began to accumulate on the front of a large bookcase, . . . then spread to the corner of the room just opposite the door, then under the old-fashioned pedestal sideboard, taking in its passage an arm-chair, . . . and at the end had reached to the corner of the hearth.

Ferguson's senses of sight, hearing, smell, and taste remained most delicate to the last; he had a peculiar discrimination not only in scents but also in wines. Beyond walking, his only exercise was dancing. His writings indicate that he had a dry and somewhat grim sense of humour.

In the short introduction to his *magnum opus*, the *Bibliotheca Chemica*, John Ferguson displays modestly his erudite and unequalled knowledge of the literature of alchemy and historical chemistry. The mere perusal of this masterly summary provides a liberal education which no chemist should forgo. Here, Ferguson takes the long view of the historian, so salutary to the type of research worker whose main object is to prove the last man wrong:

> The chemistry of the moment is also merely a phase, and by its more rapid development is so much less stable than that of three hundred years ago, when discovery made slower advance. Still the books enumerated here, unattractive as they are—even unintelligible, maybe—record the thought and experience of many men, some of them among the most skilful and far-seeing of their time. . . . Let not the modern student of science imagine that he and his work will escape the universal doom. His discoveries, his theories, the most recent, the most comprehensive and progressive, sooner or later will become mere archaeological data, to be included, or, just as likely, omitted, in a historical review of this time. . . . The history of chemistry, as indeed of all science, is but a succession of epitaphs upon forgotten men and forgotten discovery. . . . It was to mitigate this fate . . . that this gathering of writings of bygone thinkers and workers was made.

A characteristic vein of sentiment sometimes comes to the surface in John Ferguson's writings. The *Bibliotheca Chemica* is dated from his house on his sixty-ninth birthday: 23rd January, 1906; and he ends the introduction, as he says, in the old-fashioned words of old Jean Rey: 'Le trauail a esté mien, le profit en soit au lecteur, et à Dieu seul la gloire.'

British contributions to biological oceanography

C. M. YONGE

As befits a country which for centuries has ruled the waves and, in spite of U-boats, still rules them, Britain has always been to the fore in the science of oceanography. Here Professor C. M. Yonge, leader of the Great Barrier Reef Expedition of 1928-29, discusses British and other work on the fertility of the oceans.

Water covers over two thirds of the globe. Across these oceans passes the commerce of continents, while within them, from surface to profoundest depths, live innumerable forms of life which constitute a vast reservoir of food and raw material. The exploration and scientific study of the seas form the subject-matter of the science of oceanography. This is not one science but a combination of all, ranging from astronomy and physics to geology and biology. It is, moreover, the most international of sciences: beyond the narrow three-mile limit the seas are the property of no nation but the common concern of all.

Great Britain, as befits the leading maritime nation, has played a great part in the exploration of the seas. To Spain and Portugal belongs the distinction of the first crossings of the great oceans, but Britain claims, in the person of CAPTAIN JAMES COOK, the greatest of scientific navigators. His voyages represent the culmination of the great period of geographical exploration which began with the Renaissance. They also prepared the way for the biological survey of the oceans in all latitudes and all depths which was one of the great achievements of the nineteenth century.

During that period it became the custom of the Admiralty to send naturalists with their surveying vessels. It was in this capacity that DARWIN made his memorable voyage on the *Beagle*, while HOOKER accompanied SIR JAMES ROSS on the first Antarctic expedition, and HUXLEY voyaged to Australian seas in the *Rattlesnake*. By the middle of the century the results of the pioneer dredgings of FORBES, CARPENTER, and WYVILLE THOMSON succeeded in arousing popular as well as scientific interest. To what depth did life extend, and what strange forms of life dwelt in the abyss? Under the tactful stimulus of the Royal Society, the British Government was induced to embark upon an expedition of unprecedented range. In 1872 H.M.S. *Challenger* began a memorable voyage, during which she covered 69,000 miles and circumnavigated the globe, dredging and taking water and bottom samples in all depths and all latitudes. She carried a large scientific staff under the direction of Sir Charles Wyville Thomson.

With the publication of the massive series of *Challenger* reports the modern science of oceanography was established. Life had been found in the greatest depths, vast collections had been made, the nature of the bottom deposits analysed, the chemical and physical properties of the water had been determined and the course of great ocean currents followed. An example had been set that was quickly followed by all the principal maritime nations, which despatched expeditions in all directions. The result was a census of the greatest and most diverse population which exists.

Such a census has little value without knowledge of the mode of life, reproduction and development, and, above all, organization of the complex society it enumerates. Work of this type was initiated at the famous Stazione Zoologica at Naples founded by the German, ANTON DOHRN. Great work was done there by zoologists of all nations, but the broader ecological aspect received little attention. It was not unnatural that in this country, with its great commercial fisheries, the importance of the underlying causes governing the fertility of the sea should have been most keenly appreciated. Many of the basic contributions to

knowledge on this subject have been made at British marine stations, especially at Port Erin, Lowestoft, Aberdeen and Millport in Scotland, and, above all, at the laboratory of the Marine Biological Association at Plymouth.

The abundance, in total numbers and in diversity of species, of the plankton, i.e. the microscopic drifting life of the surface waters, had been increasingly realized since the middle of the nineteenth century. Now it was demonstrated that these organisms were all-important. The plant-plankton forms the true meadows of the ocean on which, either directly or by way of the small animals of the plankton, the entire marine population ultimately depends. Working at these laboratories with constant access to living animals, zoologists traced the ramifying 'food-chains' and revealed the interdependence of one organism upon another.

The fertility of any marine area was shown to depend on the local production of plant-plankton, but that in turn was controlled by chemical and physical factors. It was early discovered at Plymouth that there is a direct connexion between the summer catch of mackerel and the spring sunshine. If sunshine alone were concerned we should expect an annual increase of plankton in spring and summer, followed by a winter decline. But for the synthesis of proteins from carbohydrates the plant-plankton needs a variety of inorganic salts, especially those containing available nitrogen and phosphorus. Delicate methods for the analysis of these in terms of milligrams per cubic metre were elaborated at Plymouth, and this work has recently been extended to cover a wide variety of elements present in even smaller amounts—but of vital significance. It was shown that the supplies of available nitrogen and phosphorus represent limiting factors controlling the abundance of plant-plankton and so of all marine animals, including food-fishes and whales.

The story of annual events in the sea as thus revealed is of a spring increase followed by decline in early summer due to depletion of inorganic salts. During the winter the shallow seas which border Europe are churned up by storms and new supplies of salts come to the surface, where alone they are available to the plant-plankton. This mixing cannot occur during the summer when the warm surface waters are separated by a thermocline or discontinuity layer from the underlying colder waters. In the open waters of the oceans little such mixing occurs, and their fertility is correspondingly low. Great fisheries occur in regions where the salts from the deep water are available, in shallow seas, where cold and warm currents meet as off Newfoundland, or where deep water 'upwells' along the coast as it does in southern California.

The fertility of British waters is profoundly affected by the influx of Atlantic water, which is rich in nutrient salts. This water enters the approaches to the English Channel and, by way of the north of Scotland, the North Sea. But it fluctuates in volume annually and a clear connexion has been proved between the depth of its penetration and the yield of the fisheries. Although very accurate chemical analysis is necessary to determine the nature of the water, inshore or Atlantic, examination of the water for 'biological indicators' amongst the plankton will give this information at once. The two waters represent distinct environments inhabited by characteristic species.

These facts have led British oceanographers to seek the cause of the vagaries of our fisheries not locally but in the fluctuations of the Gulf Stream, the motive power behind the North Atlantic Drift. To this end observations were begun some years ago at the Biological Station at Bermuda with the close co-operation of American workers from the Oceanographical Institution at Woods Hole. The war has caused a temporary stoppage of this work, but it will be resumed sooner or later. It is the logical outcome of work in British seas.

During the past fifteen years Great Britain has also been engaged on the greatest of oceanographical expeditions since the *Challenger* sailed. Financed out of royalties paid on whales landed at South Georgia, the *Discovery I* and *Discovery II* have studied in repeated voyages the waters and sea-bottom of the Southern Ocean. The life-history, feeding, and habits of Antarctic whales, one of the great natural sources of fats, have been exhaustively examined. Within the tropics over a year of intensive study of coral reefs and coral-reef waters was made by the Great Barrier Reef Expedition, which worked on the north-east coast of Australia in 1928–29. Many smaller expeditions have also been made.

The cyclotron

F. FAIRBROTHER

In recent years, the word 'cyclotron' has become familiar, but exact knowledge of what a cyclotron is and does is largely confined to physicists and physical chemists. Dr Fairbrother explains the construction and purpose of this complex instrument with a happy blend of simplicity and accuracy, and describes a gigantic cyclotron now under construction.

The alchemists' dream of the transmutation of elements first came true when the late LORD RUTHERFORD in 1919 succeeded in turning a few atoms of nitrogen into oxygen by bombarding them with α-particles from a radium preparation. For many years α-particles emitted from naturally radio-active elements were the only atomic projectiles available until, in 1932, COCKROFT and WALTON at Cambridge, England, were able for the first time to bring about a transmutation by using positive ions accelerated by a high voltage. Other workers have since used increasingly high voltages, but the invention and development of the cyclotron by PROFESSOR E. O. LAWRENCE and his associates at the University of California have made possible the production of atomic projectiles of such high speed that they can penetrate into the nucleus of even the heaviest atom and bring about a wide range of atomic transmutations.

The cyclotron (shown diagrammatically in figure 1) consists essentially of a large electromagnet with circular pole pieces, between which is fixed a shallow cylindrical vacuum-tight metal chamber. Inside this chamber and well insulated from it are two hollow semicircular electrodes, known as 'dees,' rather like a shallow pillbox which has been sliced across its diameter and the two halves separated by a small gap. It is across this gap that the acceleration of the charged particles takes place. The dees are connected to a high-frequency current supply of about 100,000 volts and a frequency of the order of 10^7 cycles per second. The metal chamber is continuously exhausted by large high-vacuum pumps, and either hydrogen, deuterium (heavy hydrogen), or helium, is admitted through a needle valve. Electrons from a hot tungsten filament, striking the gas molecules, produce positively charged protons, deuterons, or helium nuclei, near the centre of the chamber; these are attracted to whichever dee happens at the moment of their production to be negative. Once they reach the inside of one of the dees they are free from the electric field across the gap, but are turned round through a semicircle by the magnetic field. It is a circumstance of fundamental importance that the time taken for such a charged particle to turn through a semicircle depends, not on its linear speed, but on the strength of the magnetic field and the characteristics of the particle. The faster particles follow a wider track and the slower ones a shorter one. By adjusting the electrical frequency and the strength of the magnetic field the particles can be brought round to the gap again just as the electric field reaches its maximum in the opposite direction, when they receive another impulse of 100,000 volts into the other dee. A given particle starting near the centre of the chamber thus follows an ever-widening spiral path, receiving an additional impulse every time it crosses the gap. When the particles reach the limit of the dees they emerge through an aperture in the circumference and

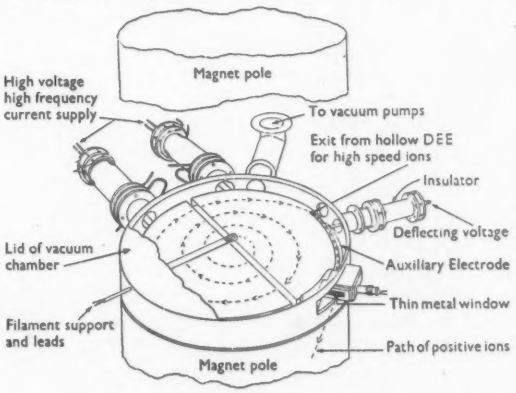


FIGURE 1

are deflected by an auxiliary electrode through a thin metal window out of the chamber.

The large number of successive impulses given to the particles speeds them up to the same extent as would a single acceleration of many millions of volts, but without many of the insulation difficulties accompanying the latter method. With given particles, the maximum speed attainable depends on the strength of the magnetic field and the radius of the dees; consequently, to attain a very high speed, a very large electromagnet is required.

Many important problems in atomic physics can be attacked with the aid of these high-speed ions, but the chief interest to the chemist and biologist lies in the transmutations which they can effect when they strike a target of a chemical element or compound. Owing to the repulsion between the two positively charged bodies, only a very small number of the projectiles actually collide with nuclei of the target atoms, but when a collision does take place the result is usually a 'nuclear reaction' in which a new nucleus, and therefore a new atom, is formed. This new atom may be one of a different element or another isotope of the target element. Thus, when a beam of several million volt deuterons strikes a crystal of common salt, some of the sodium nuclei of atomic weight 23 become sodium nuclei of atomic weight 24 by the reaction:

$$Na^{23} + \text{deuteron} = Na^{24} + \text{proton},$$

and others become magnesium nuclei:

$$Na^{23} + \text{deuteron} = Mg^{24} + \text{neutron},$$

the protons and neutrons flying away from the target. At the same time some of the chlorine nuclei of atomic weight 37 become chlorine of atomic weight 38 (Cl^{38}).

These products may be stable isotopes like Mg^{24}, or may be unstable and radio-active like Na^{24} and Cl^{38}. The Na^{24} atoms decay into stable magnesium atoms and the Cl^{38} atoms into stable argon atoms, with the emission of an electron in each case, e.g. $Na^{24} = Mg^{24} + \text{electron}$: these emitted electrons have the same character as the β-rays from radium. Other unstable isotopes decay with the emission of positrons, e.g. $Na^{22} = Ne^{22} + \text{positron}$.

This artificial radio-activity was discovered by CURIE and JOLIOT, using α-particles from a naturally radio-active source. A number of radio-elements can be obtained in this way, or by the use of neutrons from a mixture of a radium salt and beryllium powder, but the variety and intensity of the products from the cyclotron are enormously greater.

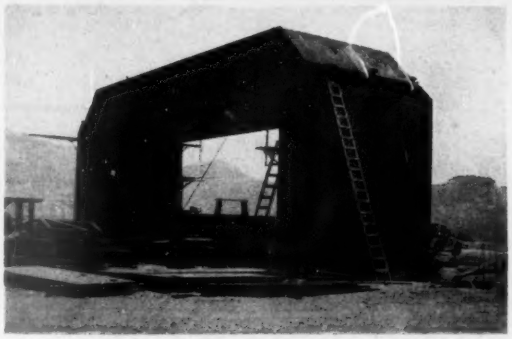


FIGURE 2

The actual yield of transmuted elements is so far only to be measured in micro-grams, but the intensity of their radio-activities makes them very easy of detection and measurement. Chemically, they behave exactly like their stable isotopic partners, hence if a small quantity of, say, radio-active chloride be mixed with a quantity of ordinary inactive chloride, the latter becomes labelled by the radio-activity, and the chlorine atoms can be identified even among other atoms of the same kind from another compound, a feat which is impossible by ordinary chemical means. A number of important chemical and biological processes have already been studied in this way, such as the exchange of halogen atoms between organic and inorganic halides, the metabolism of phosphorus and iron in animals, and the movement of inorganic salts in plants.

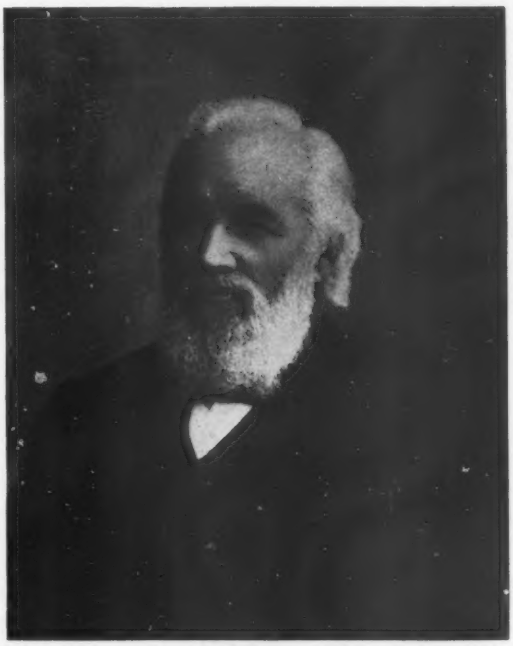
Cyclotrons have been erected in many parts of the world, including two in England, and have been made larger and larger to obtain swifter particles. The present largest at the University of California has magnet pole faces 5 ft. in diameter, and gives a beam of 16,000,000 volt deuterons or 32,000,000 volt α-particles. Even this is to be superseded by the new cyclotron being built by Lawrence and his team of workers, which is expected to give 100,000,000 volt particles, and may well open up an entirely new field in nuclear science. A photograph (by the courtesy of DR D. COOKSEY) is shown of this new giant in the course of erection (figure 2).

John Glover

N. F. NEWBURY

One of the most fruitful advances in the manufacture of sulphuric acid was the invention of the Glover tower. But the works of reference, biographical dictionaries, and even histories of chemistry had no information about its inventor, John Glover. This strange gap in our knowledge of British chemical pioneers is now filled by Mr N. F. Newbury, who has unearthed details of Glover's life from the obscurity in which they lay.

JOHN GLOVER, inventor of the tower used in the manufacture of sulphuric acid, was born in 1817 at Wallsend, near Newcastle-upon-Tyne. Apprenticed to a plumber, Glover attended the Mechanics' Institute and studied assiduously during slack periods of his work. He was first employed as a plumber, and later as a junior chemist, at the Felling Chemical Works. He suggested useful improvements in the processes used in the manufacture of alum and lead oxychloride.



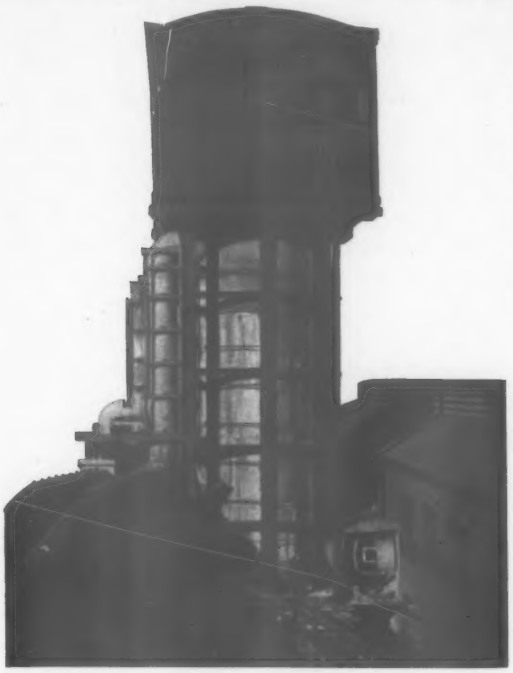
John Glover.

In 1842 he was appointed manager to the Washington Chemical Works near Durham, a position he held until 1861. Here sulphuric acid was manufactured as an intermediate in the production of hydrochloric acid and magnesium carbonate. In 1861 Glover went into partnership at the Carville Chemical Works, Wallsend, where he remained until his retirement in 1882.

Although Glover visualized his tower about 1847, he was too busy to erect it until 1859. In 1896, when he was presented with the gold medal of the Society of Chemical Industry (awarded for conspicuous service to applied chemistry), he described the conception of the tower in the following words:

> The idea occurred to me that there would be a great saving of expense and material if I could succeed in breaking up the affinity between the sulphurous and nitrous compounds in Gay-Lussac acid without going through the operations of cooling and reheating which were then performed. The first experiment was simply to heat the compound, and the result was to confer on the sulphuric acid a greater power of holding the nitre, not a particle of which was evolved. Then the idea of a deoxidizing atmosphere occurred to me, and that idea was growing in my mind for fully ten years, during which time I devoted the whole of my attention to the erection of a vitriol works for the late Mr Hugh Lee Pattison and the working out of that gentleman's process. Then I returned to my experiments, and by using a deoxidizing atmosphere succeeded in dissociating the sulphurous and nitrous compounds of the Gay-Lussac acid. The experiments were on little more than laboratory scale, but they proved the practicability of my ideas, and the Glover tower was the result.

The first tower, built in 1859 of firebricks packed with fire-resisting tiles and with its base



A Glover tower.

fixed in sulphur, functioned efficiently for a year and a half. Many such Glover towers were built, but an improved type (1864), in which the Gay-Lussac acid was diluted with the chamber acid at the top of the tower, was essentially the same in design as those used today. Glover, like Gay-Lussac, took out no patent and readily showed his working tower to visitors.

At this time sulphuric acid was usually concentrated either in badly constructed lead pans, resulting in the evolution into the air of the objectionable nitrogen dioxide, or by dilution of the nitrated vitriol with steam or hot water in boxes or steam columns. The Glover tower, however, gradually made headway in spite of opposition, and from 1868 onwards became a familiar sight on Tyneside, in Lancashire, in London, and on the Continent.

The critics of the Glover tower stated that it was expensive to build and too weak structurally to withstand continual wear and tear; that the hot sulphur dioxide reduced the nitrogen dioxide; and that the tower took three days to become warm enough to function. Glover answered these criticisms by quoting facts from his own experience. A tower built in 1868 concentrated 73,000 tons of sulphuric acid to a specific gravity of 1·75 entirely by the combustion of 15,400 tons of pyrites. The initial cost of erecting the tower was £450 and the annual cost of repair over a six-year period was £11. No signs of deterioration were apparent and no oxide of nitrogen was retained in the acid.

The functions and advantages of the tower were many. It resulted in a great saving in fuel and sodium nitrate; the concentrating plant was no longer required; the hot gases passing through the tower were cooled and carried steam into the chambers; and the Gay-Lussac acid was denitrated and concentrated. Further, although Gay-Lussac had designed his tower in 1827, it was not employed to any great extent until it could be used in conjunction with the Glover tower, since it produced concentrated sulphuric acid containing nitrogen dioxide in solution.

Today sulphuric acid of less than 95 per cent. purity is most economically manufactured in a series of Glover and Gay-Lussac towers, without the lead chambers.

Although devoted to study, Glover was friendly, energetic, and generous. Much of his spare time, especially after his retirement, was devoted to welfare work. He served on the committees of the Village Homes for Girls, the Discharged Prisoners' Aid Society, and the *Wellesley* Training Ship. As president of the Newcastle Chemical Society in 1870–72 he made a typical speech dealing with such varied subjects as sanitation, the germ theory, coal-mining, and the Leblanc process, and ended by saying:

> I believe that such of you as devote yourselves to purely scientific investigations, from the promptings of a pure and devoted love, may not, as your reward, gain material wealth, but will have formed what is of infinitely greater value, a noble character and capacity for enjoyment which wealth cannot give you.

REFERENCES

[1] *Chem. News*, 1873, **27**, 135, 152, and 163.
[2] *Ibid.*, 1874, **30**, 120.
[3] *J. Soc. Chem. Ind.*, 1896, **15**, 494 and 511.
[4] *Ibid.*, 1903, **22**, 1177.
[5] LUNGE. *Manufacture of Sulphuric Acid and Alkali* (Gurney and Jackson).

Book reviews

THE DEVELOPMENT OF SCIENCE

A Short History of Science to the Nineteenth Century, *by Charles Singer. Pp. xiv* + 399. *The Clarendon Press, Oxford.* 1941. 8*s.* 6*d. net.*

To say that this book is at least as good as others by SINGER is both high praise and simple fact. It is intended for the general reader and fulfils its purpose admirably. The scope is from Greek times to the middle of the nineteenth century, a period in which many leading scientific ideas took shape. It follows a sequence in time and deals with the forward movement of the whole of science. Of many excellent features the sound judgment of the author and his use of recent research are noteworthy. Examples are the correction of the impression that the discovery of humanism was the Greek language and the emphasis of the minor part played by formal scientific method in actual discovery. The clear exposition of the relation of general philosophical ideas to contemporary science is particularly valuable.

The author is scrupulously fair in his treatment of various nationalities in the advancement of science and—apart perhaps from his tendency to underrate the value of the alchemical school—of the importance of the various sciences in the development of human thought. He has no special pleading for the predominance of British science, yet even so its fundamental character in the whole cannot be overlooked. The two Bacons, Hooke, Boyle, Harvey, Newton, Lyell, Black, Priestley, Cavendish, Dalton, Davy, Faraday, Joule, and Darwin come into the period covered, and all exercised an immense influence on the development of science. At the same time, the interchange of ideas between lands in which freedom of thought and speech were fostered is shown to have had a beneficent influence on human progress. The book is written on a high level of scholarship but is never dull or obscure. The author has taken special pains to incorporate the latest results of historical research and, by the skilful division of the text into headed sections and by recapitulations and summaries, to keep the narrative continuous yet preserve its pattern, so that the reader does not lose the thread of the whole on the one hand or the significance of the separate parts on the other. The book is quite outstanding in its field and deserves to be widely read. J. R. PARTINGTON

PLANTS OF THE PAST

An Introduction to the Study of Fossil Plants, *by J. Walton. Pp. x* + 188, *with* 139 *illustrations. A. and C. Black Limited, London.* 1940. 15*s.*

The literature of Fossil Botany is comparatively small and there is room for a concise and general account such as PROFESSOR WALTON has provided. The presentation here adopted has much in common with the type method, one with well-recognized limitations, which are in no way discounted by a basis of selection of such types as are known in respect to both their reproductive and vegetative organs. Although this basis is not rigidly adhered to, the departures are not always those which would appear best suited to enhance the educational value of the theme. For the students for whom this work is professedly written, the inclusion, for example, of *Protopteridium* and *Thursophyton* in the chapter on the Early Vascular Plants, or *Bowmanites Romeri* and *Cheirostrobus* in that dealing with the Sphenophyllales, is dubiously advantageous when room has not been found in the chapter on the Pteridosperms for a description of either *Physostoma* or *Conostoma*, though the structure of these is essential to any adequate appreciation of the range and character of the specialization of the Lyginopteridean seeds.

Of the seventeen chapters, fifteen are devoted to brief accounts of the chief groups of fossil plants. There is also an admirable chapter on the methods of preservation and technique of investigation, which could well have been expanded with profit by the inclusion of a section on that bugbear of all beginners in this field—the interpretation of oblique sections. In this connection it may be emphasized that the elucidation of sections of fossil seeds provides perhaps the best mental discipline in three-dimensional visualization that can readily be found. Another welcome feature is the inclusion of a chapter—far too brief, as it comprises barely three pages of text—on the fossil Angiosperms. Here the statement that 'the rate of evolution

of the group during the Cretaceous and Tertiary Periods must have been exceptionally rapid' may well be a misrepresentation of the implications of the known facts. All living Angiosperms, even the most specialized aquatics, bear unmistakable evidence of their origin from terrestrial ancestors, so that it is reasonable to suppose that as an essentially land flora, possibly even evolved in relation to dry conditions, the Angiosperms may have had a long history prior to their becoming adapted to habitats likely to favour the preservation of their remains, and the character of the earliest undoubted representatives of the group makes such a suggestion by no means unlikely.

The chapter on the floras and climates of the past is again all too brief. Its six pages scarcely suffice for the display of the skeleton of the subject, still less to clothe it with the flesh of its romance. E. J. S.

SCIENCE FOR THE LAYMAN

The World of Science, *by F. Sherwood Taylor, Ph.D., M.A., B.Sc. New Impression*, 1940. *Pp. xvi* + 1063. *William Heinemann Limited, London.* 10*s.* 6*d.*

DR SHERWOOD TAYLOR'S *World of Science* is probably the best elementary survey of science published in recent years. The accurate treatment of a vast store of scientific knowledge makes it a layman's encyclopaedia, while even the professional scientist will probably find much that is new to him. Beginning with a discourse on the properties of matter considered in the main as aspects of atomic motion, the author proceeds to a discussion of power and its sources and the mechanism of simple machines. Theoretical electricity and its practical application in locomotives lead to a small though adequate treatment of transport. In Part III, on Wave Motion, the treatment of sound includes the mechanism of the gramophone, telephone, and echo-sounder. Electromagnetic waves and quanta serve to introduce light, its laws, the camera, moving pictures, radio and various types of long and short waves. The section on Chemistry proceeds from the atomic theory and an outline of the elements to compounds, formulae, hydrogen, air and oxygen, carbon and the major groups of organic compounds, and certain non-metals and metals. In Geology, Dr Taylor covers aspects of size, shape, movement, and stratified structure of the earth, distribution of land-masses and Wegener's theory of continental drift. The movements of the planets and something of the nature of the universe follow on naturally. The final section on Biology, beginning with cell-structure, leads to a consideration of man, the everyday activities of his body, heredity, and an outline of the classification of animals and the species concept. From the structure, physiology, and reproduction of various types of plant body the author proceeds to a consideration of bacteria and disease, with a concluding chapter on Evolution. The six parts of the book, containing over 1,000 well-indexed pages, are woven into a pleasing pattern. Clear and profuse illustrations and photographs are a feature of the book, which can be highly recommended to teachers, students, and indeed all who are interested in the scientific explanation of the mechanical devices in daily use and the many natural forces at work. J. H. D.

MOLECULAR SPECTRA

The Identification of Molecular Spectra, *by R. W. B. Pearse and A. G. Gaydon. Pp. viii* + 221. *Chapman and Hall Limited, London.* 1941. 42*s. net.*

The complete and accurate identification of the bands in a composite spectrogram is notoriously troublesome and tedious not only to a beginner but often also to an experienced practical spectroscopist. Although several of the existing books on molecular spectra contain tables, diagrams, and reproduced spectrograms which afford the spectroscopist considerable help in this problem, none of these books is designed for the purpose, since the main theme of most, if not all, of them is the analysis of bands and band-systems in accordance with the quantum theory of molecular spectra.

The present work is the first to be planned for the special purpose indicated by its title. It is also a valuable supplement to any of the books to which reference has been made and of which the Physical Society's 1932 *Report on Band Spectra of Diatomic Molecules* is a well-known example.

The book consists mainly of two sections: (i) a table of data for persistent band-heads in order of wave-length, and (ii) a set of lists of data for band-systems in alphabetical order of the molecules, neutral or ionized, to which they

belong. Comparison of the data for an unrecognized band-system with the data in (i) at once yields a clue to the identity of the system and molecule; then, reference to the data for that system in (ii) indicates the presence or absence of individual bands of the system. This process of double reference is now repeated for other systems of the same molecule and of any other molecule having an atom in common with it. Confirmatory evidence is obtainable from a table of persistent atonic lines and from six plates of well-chosen and beautifully reproduced spectrograms. The book will probably soon become recognized as a necessary item of the practical equipment of the spectroscopic laboratory and as the only trustworthy means of avoiding wrong assignments such as have often found their way into published papers.

W. JEVONS

THE LESS FAMILIAR ELEMENTS

Chapters in the Chemistry of the Less Familiar Elements, *by B. Smith Hopkins. Pp.* 425. *George G. Harrap & Company Limited, London.* 1939. 42*s. net.*

There seems a well-established rule that writers of text-books of inorganic chemistry should treat very briefly or entirely ignore certain so-called minor elements. This is a most unfortunate tradition because it leads many chemists to conclude that such elements are of no account. In 1923 PROFESSOR HOPKINS published his *Chemistry of the Rarer Elements*, which called attention to the great interest and usefulness of these elements and emphasized the need for their further investigation. His book met with a very cordial welcome and has become recognized as an authoritative source of information. Since 1923, however, new elements have been discovered and substantial additions have been made to our knowledge of the rarer elements. Again Professor Hopkins has undertaken the task of trying to convince chemists of the importance of the less familiar elements, and this new volume should achieve its object. The chemist who will take the trouble to read it carefully is assured of a full measure of enjoyment and a broadening of his chemical knowledge. The first of the twenty chapters deals with the Periodic Table, and here Professor Hopkins raises the fascinating problem: Is the Periodic Table complete? His answer contains the statement that 'the existence of many transuranium elements, some with large atomic weights, has been claimed, but these conclusions have been questioned.' This whets the appetite for further information, which is forthcoming in Chapter 18, on uranium. Here the author outlines the story of one of the most intriguing discoveries of recent years, viz. nuclear fission. He could perhaps have emphasized with advantage that the chemical identification of the fission products has demanded an intimate knowledge of the chemistry of many of the less familiar elements. Professor Hopkins might also have reminded his readers that with the discovery of nuclear fission the old arguments for the existence of transuranic elements are no longer conclusive. Chapter 20 is written by E. O. BRIMM, who gives an excellent account of masurium and rhenium. Little can be said about masurium, for 'contributions to our knowledge of masurium from natural sources stopped quite abruptly with the first preliminary announcements of the discovery.' In striking contrast, remarkable progress has been made in the study and chemical properties of rhenium. Turning to the less academic aspects of the rarer elements, it is quite apparent from the sections dealing with their industrial uses and importance in the arts or manufactures that already results of outstanding commercial value have been achieved. The useful alloys, for example, are nests of the less common elements. Again, it is worth remembering that an exceedingly small amount of a substance can frequently produce very great effects. In all the life-processes of both plants and animals substances present in minutest amounts often play a major role. It is to be hoped that this book will stimulate the interest of more English-speaking investigators in the less familiar elements although already their contribution is a notable one. The new volume is pleasant to read and has numerous references, but it should be recorded that in its present form it has a spiral metal binding and is without preface or index. Professor Hopkins and his collaborators have earned the gratitude of chemists for the precise, abundant, and detailed information which they have collected with such care and embodied in such a scholarly production.

W. WARDLAW

A GERMAN VIEW OF CHEMICAL WARFARE

Chemical Warfare, *by Curt Wachtel. Pp. ix* + 312. *Chapman and Hall Limited, London.* 1941. 24*s.*

This is indeed a *poisonous* book. Its author, who 'founded' the pharmacological section of the Kaiser-Wilhelm Institute as an assistant to PROFESSOR FRITZ HABER during the last war and who is now, presumably, a refugee from Nazi oppression, resident in America, defines pharmacology as 'that part of medicine which deals with poisons.' All nations, civilized and uncivilized, have always employed poisons for military ends (witness, among other examples, Shakespeare's Hamlet and Macbeth). Germany is therefore entirely guiltless of initiating poison warfare; hundreds of letters from chemists in the trenches poured into the War Ministries of Paris and London during 1914 making the same suggestion. Nevertheless Germany's miraculous scientific organization, inspired by Haber, caught the Allied troops quite unprepared, maintained triumphant superiority in chemical warfare until 1918, and will certainly employ new poisons against our civilian population in the present conflict 'when the political and tactical situation so requires.' Experts who attempt to minimize the prospective mass-slaughter are mere 'pretentious office-holders with no ideas of their own,' undermining by base ruses the reputation of truly capable chemists.

Such an astounding thesis inevitably involves numerous errors and inconsistencies. British chemists have not been backward in their appreciation of Haber (see the magnificent Haber Memorial Lecture by PROFESSOR J. E. COATES, *J. Chem. Soc.*, 1939, 1642), but WACHTEL's adulation is fulsome and frequently unjust to others. Was Haber, for instance, the 'one man in the world' who knew in December 1914 how the nitrogen of the air could be used to produce the explosives that would frustrate the early victory of the Allies (pp. 29 and 30)? And does the statement, 'medical science knows more poisons than remedies,' justify the conviction that scientific progress dooms us to endure insidious and horrible superpoisons while patients will still die from pneumonia, and 'the unfailing remedy of today will certainly be forgotten in 1943'?

It is curious that the review of American publications in the field of chemical warfare (p. 40) does not include *Chemicals in War*, by COLONEL PRENTISS (McGraw-Hill Book Co., 1937). This invaluable volume is imperfectly cited for the first time in a footnote on p. 201; its title does not appear until p. 210. Several sections of the latter half of Wachtel, however, in which the various toxic chemicals used in 1915-18 are detailed, are obvious transcriptions from Prentiss. An example is the account of phosgene on pp. 154 and 155 (compare with Prentiss, also pp. 154 and 155). Material from other sources is also utilized without proper checking, and this leads to ludicrous inaccuracies. We are told, for instance, on p. 151 that 1 litre liquid chlorine = 463 litres gaseous chlorine at 0° C., and on p. 152 that 1 litre of liquid chlorine forms 434 litres of gaseous chlorine at 25° C., whence it follows that the liquid expands much more rapidly than the gas as temperature is raised! The figure for total gas fatalities in the last war (only 30,000) is a gross underestimate, and many other important data are equally unreliable.

The style is Teutonic in complexity throughout; it is evident that the author still thinks in German even if he has ceased to think as a German. Altogether, a most unsatisfactory production, with a number of pasted-in pages of inferior-quality paper suggesting belated qualms on the part of the publisher. The price is very high.

JAMES KENDALL

PROBLEMS IN ORGANIC CHEMISTRY

Numerical and Constitutional Exercises in Organic Chemistry, *by J. L. B. Smith and Professor M. Rindl. Pp. viii* + 213. *Methuen & Company Limited, London.* 1941. 7*s.* 6*d.*

All teachers of organic chemistry know that practice in the solution of numerical exercises is a most valuable part of a student's training. It is therefore surprising to find that very few books on this subject are available, and that of those few the best are now out of date. DR SMITH and PROFESSOR RINDL set out to supply the deficiency, and are to be congratulated on the result. Their book is a well-designed and admirably executed scheme, and the student who works through it conscientiously will not only have attained a thorough grasp of the main principles of elementary organic chemistry but will be in a position to interpret the data he obtains when he begins original research.

Notes on contributors

SIR WILLIAM BRAGG,
O.M., K.B.E., F.R.S.

Is one of the best-known names in contemporary science, and a scientist who has won international honour in the world of physics. Sir William originally made his mark with his researches in connection with the elucidation of crystal structure by X-ray methods, in which work he has since been joined by his distinguished son, Professor Sir W. L. Bragg. Father and son are known as outstanding authorities on their subject. Sir William has gained wide scientific distinctions and has the award of the rare Order of Merit, of which there are only twenty-four holders. He has recently completed his term of office as President of the Royal Society.

H. SPENCER JONES,
M.A., Sc.D., B.Sc., F.R.A.S., F.R.S.

Has held the position of Astronomer Royal since the year 1933. Dr Jones was born in London in 1890 and was educated at Latymer Upper School, Hammersmith, and Jesus College, Cambridge, where he had a brilliant academic career. From 1913-23 he was Chief Assistant at the Royal Observatory at Greenwich, and from 1923-33 held the post of His Majesty's Astronomer at the Cape of Good Hope. He is known throughout the world not only for his distinguished original contributions to astronomy but for his skill in explaining to laymen the most abstruse astronomical and cosmological conceptions and theories.

C. H. WADDINGTON,
M.A., Sc.D.

Is one of the most brilliant of the younger school of British scientists. He was born in 1905 and educated at Clifton College and Sidney Sussex College, Cambridge. He specializes in the study of heredity, and particularly in that branch of it known as genetics. He has wide interests and the gift of virile and fluent expression. He has held the Gerstenberg prize for embryology of the Royal Belgian Academy, and is at present a Fellow of Christ's College, Cambridge.

J. G. CROWTHER

Is well known as a scientific journalist, as well as being the secretary of the Science Committee of the British Council. He holds the position of scientific correspondent of the *Manchester Guardian* and is author of several successful books on science for the general reader. He has travelled extensively in America and Europe as well as in the Soviet Union, and has first-hand knowledge of many of the most up-to-date scientific laboratories in the New World as well as the Old.

A. L. BACHARACH, *M.A., F.I.C.*

Is one of the foremost authorities on nutrition and dietetics in the British Isles. He was born in 1891 and was educated at St. Paul's School and Clare College, Cambridge. On taking his degree he entered industry by way of the Wellcome Chemical Research Laboratories. After working there for some time he joined the staff of Glaxo Laboratories Limited in January 1920, and is now head of the biochemical department of this firm. He is the author of a large number of papers, reviews and technical articles and is honorary treasurer of the newly formed Nutrition Society.

G. V. JACKS, *M.A., B.Sc.*

Has specialized in 'soil science' since his graduation from the university. He is 40 years of age and was educated first at Magdalen College School and afterwards at Christ Church, Oxford. He was there awarded a post-graduate research scholarship by the Ministry of Agriculture and travelled extensively in Germany, Scandinavia and Russia. From 1929-31 he was Lecturer in Soil Science at the Imperial Forestry Institute, Oxford, and has since held the post of Deputy Director of the Imperial Bureau of Soil Science at Rothamsted.

JOHN READ, *Ph.D. (Zürich), M.A., Sc.D. (Cantab.), F.R.S.*

John Read is a Somerset man and proud of it. Born in 1884, he was educated at Sexey's School, Bruton, Finsbury Technical College, and the Universities of Zürich, Manchester, and Cambridge. He is Professor of Chemistry in the University of St. Andrews, to which he was translated in 1923 after seven years as Professor of Organic Chemistry in the University of Sydney, Australia. He is an authority on the chemistry of the natural products of Australia, on stereochemistry, and on the history of chemistry.

C. M. YONGE, *Ph.D., D.Sc.*

Is another of the younger scientists. He has trodden in the footsteps of Captain Cook. He was born in 1899 and educated at Silcoates School, Wakefield, and at Edinburgh University. After a period of research work, he became, in 1925, Assistant Naturalist at the Marine Biological Association, Plymouth, and two years later went to Cambridge as Balfour student. In 1928 he led the Great Barrier Reef Expedition to Australia, and on returning in 1929 went back to the Marine Biological Association at Plymouth as physiologist. Since 1933 he has been Professor of Zoology in the University of Bristol. He is also a member of the Advisory Committee of Fishery Research to the Development Commission and has published a number of books and papers on biology.

F. FAIRBROTHER, *D.Sc.*

Is Lancashire born, bred, and educated. He was born in 1894 at Heywood, and educated at Manchester Grammar School and Victoria University, Manchester. Since 1919 he has been a member of the staff there and now holds the title of Reader in Inorganic Chemistry. His researches have been chiefly in connection with electrokinetic phenomena, dipole moments, and electrolytic dissociation processes. In 1936 he was awarded a Leverhulme Research Fellowship and spent the year 1937 in California working in the laboratories of Professor E. O. Lawrence at Berkeley and of Professor Linus Pauling at Pasadena.

N. F. NEWBURY,
M.A., M.Sc., A.I.C.

His chief experience has been in the field of education. He has had seventeen years' experience of teaching, and is also the author of several books dealing with the subject. He is a graduate of Sheffield University and also of Liverpool University.

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